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Small is beautiful: The processing of the left periphery in German

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Abstract

Event-related potentials (ERPs) were used to examine the interplay of structure building and the integration of morphosyntactic information during incremental parsing. The critical sentence conditions examined the processing of verbs that were ambiguous between a clause-initial finite main verb analysis and an analysis as an (homophonous) infinitival verb in a fronted verb phrase. The task interacts with particle stripping, since particles are stranded if the finite verb is fronted. Conversely, if the particle is present, the potentially finite verb cannot be the fronted finite verb. This is a top-down (grammar-driven) prediction of the parser with immediate impact on the ongoing structure building process of the parser. The ERP results provide first of all straightforward indications for a minimality-driven parsing process (motto: assign immediately the minimal convergent structure to the available input string, and disregard ambiguities that would result in more complex assignments). Second, they show that the parser cross-checks (validates) the minimality-driven outcome for its compatibility with the locally available morpho-syntactic information (finiteness, agreement, particle stripping). Furthermore, we suggest a simple metric which resolves apparent contradictions with respect to previous ERP findings for reanalysis in structural ambiguities and which solely depends on the complexity of structural reanalyzes (that is, whether the required structural modification proceeds within a single clause, or takes place across a sentence boundary).

Keywords: Morphosyntax; Minimal Attachment; Language processing; N400; P600; Reanalysis

1. Introduction

1.1. Minimality as a processing strategy

One of the tenets in the study of language comprehension (in psycholinguistic theory) is the assumption that the language processing system proceeds incrementally. This means that during the processing of a sequential input of words (e.g. during listening of speech or reading a text) each incoming word is integrated syntactically and maximally interpreted immediately as it is encountered (Crocker, 1994; Stabler, 1994). Under such a view one of the crucial issues is how the human sentence parsing system deals with incomplete or even ambiguous input information. It is a well-established observation that in the case of ambiguous syntactic information, the sentence parsing system proceeds

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instantaneously while committing itself to a (preferred) structural analysis. This is the case despite the possibility that later information might reveal that the adopted analysis was incorrect. Such a non-procrastinating behavior becomes intuitively evident in so-called garden path sentences such as (1; from Bever, 1970):

(1) The horse raced past the barn fell.

In (1), the verb *raced* is locally/temporarily ambiguous: it could either be interpreted as the main verb of an active clause (*The horse raced past the barn*) or as a past participle introducing a reduced relative clause (*The horse (that) raced past the barn*).[1] Yet most readers, at least initially, will perceive (1) as ungrammatical when stumbling across the sentence-final word *fell*. This indicates, that during incremental processing of (1) *raced* is preferentially analyzed as the main verb of an active main clause instead of the correct reduced relative clause structure.

In serial (modular) models of sentence parsing it is assumed that the principles guiding the initial parse adhere to principles of syntactic economy: the parser incrementally computes an initial structure which is the simplest one justified by the available input (Frazier, 1978; Frazier and Rayner, 1982; Gorrell, 1995; Pritchett, 1992). As a consequence, each processing step constructs the simplest possible structure, thereby resolving potential ambiguities by adopting the simplest analysis. This modus operandi of the language comprehension system is captured in parsing preferences such as Minimal Attachment (Frazier, 1978), or meta-principles such as Simplicity (Gorrell, 1995), or Minimal Everything (Fodor, 1998; Inoue and Fodor, 1995). The common denominator underlying all these proposed principles is the supposition that syntactic-ambiguity resolution is accomplished by a hierarchically organized processing architecture, in which syntactic information has priority over other information types: During a first stage the parser only considers word-category information while constructing the simplest syntactic structure. During a second stage other information types (e.g. lexical-semantic or morphosyntactic information) come into play. When grammatical preferences support the wrong analysis, garden-path effects are predicted.

By contrast, parallel (interactive, constraint-based) models deny the primacy of syntactic structure building during sentence processing. In their view, syntactic information is only one of many interacting information types which constraint sentence interpretation from the very beginning (e.g. MacDonald et al., 1994; Trueswell and Tanenhaus, 1991, 1994). It is assumed that syntactic ambiguities first trigger the parallel activation of all analyses consistent with the grammar. Then, the coordination of multiple types of knowledge, including semantic knowledge and statistical knowledge about the structural biases of words finally leads to the convergence in a single solution. Hence, ambiguity resolution is regarded as a continuous process in which the most likely syntactic alternatives are evaluated with respect to evidence provided by all available information types (e.g. Trueswell et al., 1994). When evidence accumulates in favor of the wrong analysis, garden-path errors arise.

In the light of these model-theoretic controversies, a number of studies investigated whether and how various types of non-syntactic linguistic information (e.g. frequency, plausibility, etc.) might influence first-pass parsing decisions (for example, MacDonald et al., 1994; Trueswell et al., 1994). Although there is some evidence supporting interactive constraint-based models (e.g. Trueswell et al., 1994; Hare et al., 2007), others have argued against such a view and opted in favor of serial depth-first models (e.g. Rayner et al., 1983; Clifton et al., 2003).[2] Moreover, recent findings from experimental research with the event-related brain potential method seem to provide evidence for a syntax-first behavior, by showing that the human sentence processing mechanism, at least initially, proceeds hierarchically (Hahne and Friederici, 2002; Friederici, 2002). However, this doesn't resolve the issue whether syntactic and non-syntactic information might interact at a later processing stage. In sum, it is still a matter of debate which pieces of information are taken into account at which point in time during the incremental processing of a linguistic input.

A large portion of the experimental research on parsing strategies of the language comprehension system has centered on the investigation of various types of attachment preferences (e.g. prepositional phrase attachment in NP–VP attachment ambiguities, relative clause attachment), coordination ambiguities (e.g. NP/VP-coordination),

[1] For a completely different view see McKoon and Ratcliff (2003, 2005). They claim that at least reduced relative clauses with (unergative) verbs that denote an 'internally caused' event (Levin and Rappaport Hovav, 1995) are not ambiguous at all, because in these cases only the main clause analysis is grammatically licensed whereas the reduced relative analysis isn't. For a critical discussion of this view see Hare et al. (2007).

[2] For a third option see, for example, van Gompel et al. (2001, 2005) who have argued against both, constraint-based and syntax-first models in favor of variable-choice reanalysis models (such as the unrestricted race model). However, see the critical objection of their results in Green and Mitchell (2006).

syntactic function ambiguities (e.g. subject–object or object–object ambiguities), or reduced relative clauses (RRCs; cf. example 1) which have played a prominent role in this framework (Altmann, 2006). Of particular interest was the question whether certain classes of constraints, such as verb-specific information and referential context, might influence the initial syntactic commitments (as claimed by constraint-based models).

In this spirit, Ferreira and Clifton (1986) investigated in an eye-tracking study whether readers make use of semantic information (including animacy) to avoid syntactic misanalysis. They showed that in sentences like *The defendant examined by the lawyer* ... reading was disrupted independent of contextual constraints when a sentence fragment that could be understood as a subject plus a main verb (MV) was disambiguated toward the normally unpreferred RRC analysis through the occurrence of a *by*-phrase. Importantly, this was the case even when the MV analysis was rendered implausible by using an inanimate noun as the subject of the sentence (as in *The evidence examined*...). They argued that these findings speak against a constraint-based account and rather supports a serial, depth-first model in which grammatical constraints have priority.[3] Structural preference like these can nicely be captured by assuming that the parser adopts an economy-based parsing preference like the plain-vanilla Minimal Attachment strategy (Frazier, 1978). The Minimal Attachment strategy stipulates that each incoming lexical item is to be attached into the phrase marker with the fewest syntactic nodes consistent with the well-formedness rules of the language (‘‘Do not postulate any potentially unnecessary nodes.’’ (Frazier, 1987)). It thus predicts that the verb *raced* in *The horse raced past the barn* is more readily interpreted as an active intransitive verb in the main clause than as the passive participle of a transitive verb in a RRC modifying *the horse* (because the former structure is the one with fewer nodes; MV = [$_S$ [$_{NP}$ the horse] [$_{VP}$ raced ...]]; RRC = [$_S$ [$_{NP}$ the horse [$_S$ [$_{VP}$ raced ...]]] [VP...]]).

In the present study, we add an entirely new facet to the prevailing paradigm based on the particularities of German syntax. Here, we are not only interested in the question whether a minimality-based syntax-first parsing strategy is operative at the phrase structure level (Minimal Attachment) during sentence processing (ambiguity resolution), but furthermore, whether there is an interaction of such a minimality-based parsing heuristic and morphosyntactic information encoded in certain complex verb types in German which have the property that an attached particle obligatorily has to be separated from the verb stem in certain syntactic positions. To this end we will investigate a specific type of structural ambiguity that (in some respects) is similar to MV/RRC-ambiguities, but at the same time avoids many of the problems associated with them (cf. the critical comments in McKoon and Ratcliff, 2007). Recall that the cause of MV/RRC-ambiguities lies in the ambiguity between a finite and non-finite verb reading. Here we use a similar morphological ambiguity (homonymy) although with different consequences: main verbs that are homonymous between a finite and non-finite reading result in a structural ambiguity of the left periphery in German declarative clauses. Note, that this type of structural ambiguity is not possible in English, as English does not have the pan-Germanic V2 declarative clause structure, that is, a phrase in the initial position (that may contain an infinitival verb) followed by the finite verb (see section 1.2 for details). In particular, this type of ambiguity is especially attractive because it applies to all verbs in German independent of their lexical-semantic properties. Hence, unlike English RRCs, there is no contextual or semantic bias for one reading over the other. Furthermore, the resolution of the ambiguity is strictly local (and not delayed until the sentence-final position as for example in (1)).

In sum, the present manipulation not only gives us the possibility to investigate the parsers’ preferences with respect to structural ambiguities (via Minimal Attachment), but also furthermore allows us to investigate whether and when morphosyntactic information encoded in verbal prefixes might interact with initial parsing decisions.

Before we describe the present experimental procedure as well as our hypotheses in more detail, we briefly will discuss the grammatical properties of the stimulus material employed in the subsequent experiments.

1.2. The grammatical properties of the stimulus material

German is a V-second language. This means that the left periphery of a German declarative main clause has the following uniform structure: a single phrase is followed by the finite verb (2a). Second, German is head-final for the

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[3] Trueswell et al. (1994) argued against this conclusion. By improving the materials of Ferreira and Clifton (1986) they could show that little or no trace remained of the garden-path induced in sentences with an inanimate noun. They concluded that plausibility did override the structural preference and, thus, took this as evidence in favor of a constraint-based account. However, see the critical discussion of their findings in Clifton et al. (2003).

verbal phrases. Arguments precede the verbal head (2b). As for the XP position and the position of the finite verb in (2a), both positions are considered derived positions. A phrase is moved to the XP position (let us say the ZP of (2b)), and the finite verb is moved from its VP-internal position to the position 'V_{fin}' in (2c).

(2) a. [XP [$V_{fin.}$ [. . .]]]
b. [$_{VP}$ YP ZP V°]
c. [ZP_j [$V_{fin\text{-}i}$ [[$_{VP}$YP e_j e_i]]]]

The choice of the phrase for the initial position in (2a) is syntactically optional. In particular, the fronted XP phrase may even be a VP. In this case, XP contains a non-finite verb, as indicated in (3).

(3) [[XP V] [V_{fin} [. . .]]]

If the first verb in (3) is morphologically ambiguous,[4] as illustrated in (4a), the string, consisting of the XP portion and the first V, entails a local structural ambiguity for the processor. (4a) may be analyzed as a sequence of a DP (in the position of the XP), followed by the finite verb (4b), or as a VP in the position of the XP (4c). The choice between (4b) and (4c) is a case for the minimality strategy of processing. Minimality favors (4b) as the minimal structure in comparison with (4c).

(4) a. [Den Katalog bestellen ·····]
'the catalog order' (to order the catalog)
b. [Den Katalog [bestellen$_{fin}$ [·····]]][5]
c. [[Den Katalog bestellenV_{infin}]$_{VP}$ [·····]]][6]

The grammar of German supplies the parser with different expectations for each case, as to the category of the immediately following element. In the case of (4c), the next element almost certainly[7] will be a verb, either finite (5a) or not (5b). If it is not finite, the expectation is reapplied recursively.

(5) a. [[Den Katalog bestellen] [*müssen*$_{fin\text{-}i}$ [wir morgen e_i]]]
'the catalog order must we tomorrow'
b. [Den Katalog bestellen *müssen*] werden$_{fin\text{-}i}$ [wir morgen e_i]]]
'the catalog order must shall we tomorrow'
(The catalog, we shall have to order tomorrow)

In the case of (4b), the expectation will be less deterministic. What follows is simply the rest of the clause. So, in (5a), the parser can predict, given the lexical argument structure of *bestellen* 'to order' that there must be at least a subject argument. But it need not follow immediately, since other elements (e.g. adverbs) may precede the subject.

Particle verbs deserve special attention. Fronting the finite verb to the V-second position involves the stranding of the particle in the VP-internal position of the verb (6a). The particle is obligatorily stripped off (6b). On the other hand, the fronting of a VP pied-pipes the particle (6c). In this case, stripping off the particle would be ungrammatical (6d).

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[4] In German, the form of the infinitive (V-stem plus the ending '-en') is non-distinct from the finite forms of the verb for 1st person plural present and 3rd person plural present: *bestellen* '(to) order'; *wir bestellen* 'we order'; *sie bestellen* 'they order'.

[5] As in: *Den Katalog bestellen wir morgen* – 'the catalog order we tomorrow' (the catalog, we order tomorrow).

[6] As in: [*Den Katalog bestellen*] *müssen wir morgen* – 'the catalog order must we tomorrow' (the catalog, we must order tomorrow).

[7] The only other possibility is that the fronted VP contains extraposed material. This would follow the verb, as in the case of the extraposed relative clause in (i):

(i) [*Den Katalog bestellen* den sie dir empfahl] *müssen wir morgen* – 'the catalog order which she (to) you recommended must we tomorrow' (we shall have to order the catalog tomorrow that she recommended to you).

(6) a. Jetzt steht$_i$ niemand *auf* e$_i$
now stands nobody up
b. *Jetzt *auf* steht$_i$ niemand e$_i$
now up stands nobody
c. [Aufstehen]$_{VP}$ darf hier niemand
up stand may here nobody
d. *[Stehen]$_{VP}$ darf hier niemand auf
stand may here nobody up

These patterns are a consequence of the different requirements of each of the two fronting processes (i.e. phrasal movement of XP and head movement of the finite verb). Fronting the finite verb means fronting an *atomic* lexical head to a *head* position. Fronting to the XP position, however, means fronting an element to a *phrase* position. So, the minimal VP to be fronted to the XP position is the verb together with the particle.

This complementarity of distribution – particle *plus* verb in the case of the XP position, verb *without* the particle in the case of the finite verb – disambiguates the pattern (4a) if the morphologically ambiguous verb is a particle verb:

(7) a. [[Den Katalog abbestellen]$_{VP}$ . . .
'the catalog de-order' (unsubscribe the catalog)
b. [Den Katalog [bestellen$_{fin\text{-}i}$ [········ ab-e$_i$]]]

Unlike in (4a), the potentially finite verb in (7a) cannot be the finite verb in this structural position since in this case the particle could not be attached to the verb. It would have to be stranded, as in (7b).

1.3. Stimulus material and hypotheses (general)

The stimulus material consists of the following sets (8 and 9) of data patterns. (8) illustrates the patterns that allow manipulating the local context for the identification of the finite verb.

(8) a. XP V$_{fin/inf}$ . . . — locally ambiguous because of ambiguous finiteness
[Den Antrag] bearbeiten. . .
[the application$_{ACC}$] work-on$_{fin/inf}$
b. XP V V$_{Aux\text{-}fin}$ . . . — locally ambiguous at the position of V, as in (8a)
[Den Antrag] bearbeiten sollten. . .
[the application$_{ACC}$] work-on should$_{fin}$
c. XP ptc+V$_{inf}$ . . . — locally unambiguous because of the particle
[Den Katalog] abbestellen. . .
[the catalogue$_{ACC}$] de-order$_{inf}$ . . .
d. XP ptc+V V$_{Aux\text{-}fin}$ . . . — locally unambiguous because of the particle
[Den Katalog] abbestellen sollten. . .
[the catalogue$_{ACC}$] de-order should$_{fin}$

Local ambiguity arises at the position of V in (8a/b) because of the non-distinctness of the infinitival form of the verb (V-stem plus the ending *-en*) and some of the finite plural forms in the present tense (1st person: *wir bearbeiten*, 'we work-on'; 3rd person: *sie bearbeiten*, 'they work-on'). On the one hand, this allows to test the kind of (non-)commitment of the parser with respect to minimality assumptions at the position of V (and on the following item) in all cases, and on the other hand the integration of information coming from finiteness and particle distribution in (8c/d) in comparison with (8a/b).

In addition, the patterns (9) were taken in order to control for the expectations on the position following the finite verb. If a verb is construed as the finite verb in (a), the pronoun is a likely continuation of the clause. However, if the verb is construed as non-finite, a finite verb is expected to follow immediately, and not a pronoun.

(9) a. XP (ptc+)$V_{fin/infin}$ pronoun ...
b. XP (ptc+)V $V_{Aux\text{-}fin}$ pronoun...

In the following, we assume that the language comprehension system predicts and integrates sentential components on the basis of economy principles, like Simplicity (Gorrell, 1995), Minimal Attachment (Frazier, 1978, 1987), or Minimal Everything (Inoue and Fodor, 1995). For the present purposes we will draw on the definition of *Minimal Attachment* as formulated in Frazier and Fodor (1978:320)[8]:

> The Minimal Attachment principle: "... stipulates that each lexical item (or other node) is to be attached into the phrase marker with the fewest possible number of nonterminal nodes linking it with the nodes which are already present."

The principle implies that only those syntactic constituents that are necessary for a minimal structure are postulated. With regard to German declarative clauses it is assumed that an initial unambiguously accusative-case marked object leads to the prediction of a finite verb and a subsequent subject (cf. Gibson, 1998).[9] In cases where the upcoming verb is morphologically ambiguous between a finite and non-finite verb form, the parser should prefer the former in order to avoid conflicts with minimality preferences. Thus, it is predicted that in a structure like (8a) the local ambiguity of the verb is resolved in favor of a finite reading of the verb and thus in favor of a V-second structure. By contrast, if an initial object is followed by a particle + verb combination as in (8c), the verb is not compatible with a minimal (V-second) structure and thus should lead to increased processing costs when the parser exploits the information that the particle verb must be a non-finite verb in a constituent preceding the finite verb. Considering the position of the finite modal verb following the main verb as in (8b) and (8d) the situation is as follows: based on minimality, the main verb in (8b) is interpreted as a finite verb (in V-second position) and the appearance of a subsequent noun phrase (as the subject) is the most likely continuation. Therefore, the encounter of a finite modal verb does not match the minimality-based parsing preference and enforces the reanalysis of the preceding DP-V sequence as a fronted VP, thus leading to increased processing costs. By contrast, in a structure as (8d) in which a particle verb follows the initial DP, a finite modal verb is expected because the parser is already committed to reanalyze the initial DP-V sequence as a fronted VP when the particle verb is encountered. These assumptions lead to a further prediction with respect to the processing of the pronoun following the main verb (as in (9a)). For particle verbs the personal pronoun is incompatible with the existing sentence structure (which requires a verb to follow the particle verb, preferentially finite) and thus should elicit a word-category violation resulting in ungrammaticality.

To summarize, at the position of the main verb we expect increased processing costs for (8c) relative to (8a), whereas the opposite should be the case at the position of the finite modal verb: Here (8b) should lead to increased processing difficulties in comparison to (8d). Because we argue that in both cases the increased processing costs are consequences of the adherence to structural minimality, we don't expect any qualitative or quantitative differences between them. Moreover, at the position of the pronoun in (9a) we expect increased processing costs for particle verbs in comparison to prefix verbs due to the ungrammaticality of the former.

2. Experiments

In the present experiments we will use scalp-recorded event-related brain potentials (ERPs) time-locked to the presentation of a stimulus. ERPs are negative and positive voltage changes in the ongoing electroencephalogram. They provide continuous measurement of the brain's electrical activity with high temporal resolution and have been shown to be sensitive to a variety of sensory and cognitive processes including language comprehension (Hillyard and Picton, 1987; Friederici, 2002). For a more detailed description of the ERP methodology, the reader is referred to the appendix Bornkessel-Schlesewsky and Schlesewsky (this issue).

[8] Note, however, that the present hypotheses and arguments do not depend on this specific formulation of the minimality principle.

[9] Frazier and Fodor express this implication in terms of phrase structure rules: "Minimal Attachment also presupposes minimal rule accessing. If the well-formedness conditions are mentally represented in the form of phrase structure rules, each node between a lexical item and the top S node of the phrase marker will require the accessing of another rule, to determine in what configurations it may properly appear. For example, if an NP node has been established at the beginning of a sentence, Minimal Attachment will require it to be entered as immediate daughter to the top S node, by reference to the rule S → NP–VP." (Frazier and Fodor, 1978:321-2).

2.1. *Experiment 1*

The aim of Experiment 1 was to examine the electrophysiological response to conflicts arising through the interaction of the parser's preference to adhere to structural minimality (V-second) and the availability of contradicting morphosyntactic information encoded in verbal elements thereby enforcing a structurally more complex analysis (fronted VP). The critical sentence material employed in Experiment 1 is illustrated in (10; the two critical regions for the ERP comparisons are underlined).

(10) a. Prefix verbs, verb-second (=40)
[Den Antrag] <u>bearbeiten</u> <u>sie</u> dennoch nicht.
[the application$_{ACC}$] work-on$_{3.pl.pres}$ they$_{3.pl}$ anyhow not
'The application, they don't work on anyhow'
b. Prefix verbs, fronted VP (=40)
[Den Antrag <u>bearbeiten</u>] <u>sollten</u> sie dennoch.
[the application$_{ACC}$ work-on$_{infin}$]$_{VP}$ should$_{3.pl.past}$ they$_{3.pl}$ anyhow
'The application, they should work on anyhow'
c. Particle verbs, verb-second (=40)
*[Den Katalog] <u>abbestellen</u> <u>sie</u> aber bestimmt.
[the catalogue$_{ACC}$] de-order$_{3.pl.pres}$ they$_{3.pl}$ but surely
d. Particle verbs, fronted VP (=40)
[Den Katalog <u>abbestellen</u>] <u>könnten</u> sie bestimmt.
[the catalogue$_{ACC}$ de-order$_{infin}$]$_{VP}$ could$_{3.pl}$ they$_{3.pl}$ surely
'The catalog, they could cancel surely'

As is apparent from (10), the critical conditions were simple declarative clauses which instantiated a 2 × 2 design crossing the factors verb type (prefix vs. particle verbs; 10a/b vs. 10c/d) and position/finiteness (finite verb in V-second vs. main verb infinitive as part of a fronted VP; 10a/c vs. 10b/d).

Our hypotheses were as follows. In accordance with our general hypotheses we expect to observe increased ERP signatures as a reflection of increased processing costs for particle verbs relative to prefix verbs at the position of the main verb, and for prefix in comparison to particle verbs at the position of the modal verb, respectively. In addition, in sentences with particle verbs, for which the integration of the personal pronoun causes the ungrammaticality of the phrase, we expect increased ERP signatures in comparison to prefix verbs at the position of the pronoun. Moreover, these ERP effects are expected to be qualitatively different from the increased processing costs at the verb positions because they stem from an outright ungrammaticality (word category violation).[10]

2.1.1. *Materials and methods*

2.1.1.1. Participants. Nineteen students from the University of Marburg participated in the Experiment (12 female, mean age 22.1 (sd = 1.73) years; age range 20–26 years). All participants were right-handed (as assessed by an adapted and modified German version of the Edinburgh Handedness Inventory; Oldfield, 1971), monolingual native speakers of German and had normal or corrected-to-normal vision. Participants gave written informed consent before the experimental session. An additional four participants were excluded from the final data analysis because of difficulties in performing the acceptability task (two subjects consistently accepted sentences with congruency mismatches, two consistently rejected sentences with a fronted VP).

[10] Note, that even if the parser would predict extraposed material as part of the fronted VP (see footnote 12) – contrary to minimal attachment preferences – personal pronouns nevertheless would be ruled out. The structure (2b) could be saved only on the assumption that this is the beginning of a clause with left dislocation of a VP:

(i) Den Katalog abbestellen, sie würden das sicherlich nicht telephonisch machen.
the catalogue de-order, they would this surely not telephonically do

Yet, left dislocation in spoken German is signalled by a clear intonation break, or in writing, by a comma. So, under normal conditions, the processor would be 'warned' in each case.

2.1.1.2. Materials. Each sentence had an unambiguously accusative case marked singular noun phrase in the initial position followed by a main verb. The element after the main verb was either a subject pronoun (10a/c) or a finite modal verb preceding a subject personal pronoun (10b/d). Crucially, the type of main verb was balanced between prefix and particle verbs. All verbs were matched for length and contained exactly four syllables. Forty sentences were presented in each of the critical conditions, thus resulting in a total of 160 critical sentences per experimental session. In addition, 240 sentences of various types served as fillers. One third of the filler sentences contained a grammatical violation (either a congruency, case, or semantic mismatch). The entire material was assigned to 4 randomized lists of 400 sentences each.

2.1.1.3. Procedure. Sentences were presented visually in the center of a computer screen. Each trial began with the presentation of an asterisk (1000 ms) followed by a 200 ms blank screen in order to fixate participants' eyes at the centre of the screen and to alert them to the upcoming presentation of the sentence. The sentence was presented word-by-word with 500 ms for the initial complex noun phrase, 450 ms for each following single word and an ISI of 150 ms each. After the presentation of the sentence, participants were asked to complete an acceptability judgment task (signaled by the presentation of a question mark), which required judging the sentences as acceptable or unacceptable. Participants responded by pressing the left and right mouse button for 'yes' or 'no', respectively. The time window for the button press was restricted to 3000 ms. Between the trials there was an inter-trial interval (ITI) of 2100 ms. Participants were asked to avoid movements and eye-blinks during the presentation of the sentences. For each participant, the acceptability judgment task required the answer 'yes' equally often as the answer 'no'. All experimental sessions began with a short training session followed by 5 experimental blocks, with a short break between each of them. Each experimental session lasted approximately 2 h (including electrode preparation). The EEG was recorded by means of 27 sintered Ag/AgCl-electrodes fixed at the scalp by means of an elastic cap (Easy Cap, Herrsching-Breitbrunn, Germany). The ground electrode was positioned at C2. Recordings were referenced to the left mastoid, but re-referenced to linked mastoids offline. The electrooculogram (EOG) was monitored by means of electrodes placed at the outer canthus of each eye for the horizontal EOG and above and below the participant's left eye for the vertical EOG. Electrode impedances were kept below 5 kΩ. All EEG and EOG channels were amplified using a BrainVision BrainAmp amplifier (time constant 0.9 Hz, high cutoff 50 Hz) and recorded with a digitization rate of 250 Hz. The data were filtered offline with a 0.3–20 Hz bandpass filter.

2.1.1.4. Data analysis. For the acceptability judgment, mean acceptability ratings were computed. For the statistical analysis, we computed a repeated measures analysis of variance (ANOVA) containing the condition factors VERB (prefix vs. particle verbs) and POSition (main verb in V-second vs. part of a fronted VP) and the random factors participants (F_1) and items (F_2). For the ERPs, averages were calculated per condition per participant from 200 ms prior to the onset of the critical stimulus item to 1000 ms post onset, before grand-averages were computed over all participants. Trials containing ocular or other artifacts were excluded. ANOVAs were computed using the condition factors VERB and POS. In addition, we included the topographical factor region of interest (ROI). Lateral and midline electrodes were analyzed separately. Lateral ROIs were defined as follows: left-anterior (F7, F3, FC5), left-posterior (CP5, P7, P3), right-anterior (F8, F4, FC6), and right-posterior (CP6, P8, P4). For the midline, each electrode (Fz, Cz, Pz, Oz) formed a ROI of its own. All statistical analyses were carried out in a hierarchical manner, i.e. only significant interactions ($p < 0.05$) were resolved. To avoid type I errors resulting from violations of sphericity, the correction proposed by Huynh and Feldt (1970) was applied.

2.1.2. Results

2.1.2.1. Behavioral data. Mean acceptability ratings for the acceptability judgment task are given in Table 1. Because participants were required to perform the judgment task via a delayed button press (in response to the onset of a question mark), reaction times are not informative and therefore will not be reported here.

For the acceptability ratings, a repeated measures ANOVA revealed a main effect of VERB ($F_1(1,18) = 72.77$, $p < 0.001$; $F_2(1,78) = 649.68$, $p < 0.001$) and POS ($F_1(1,18) = 74.70$, $p < 0.001$; $F_2(1, 78) = 621.16$, $p < 0.001$) as well as an interaction VERB $\times$ POS ($F_1(1,18) = 74.60$, $p < 0.001$; $F_2(1,78) = 734.31$, $p < 0.001$). Resolving this interaction by VERB showed main effects of POS for both prefix ($F_1(1,18) = 7.64$, $p < 0.015$; $F_2(1,39) = 5.65$, $p < 0.025$) and particle verbs ($F_1(1,18) = 75.74$, $p < 0.001$; $F_2(1,39) = 855.69$, $p < 0.001$).

Table 1
Behavioral results for the acceptability judgment task in Experiment 1

Condition	Acceptability judgment in %
Prefix verbs	
V-second	96.82 (3.98)
Fronted VP	94.47 (5.93)
Particle verbs	
V-second	29.44 (34.38)
Fronted VP	87.38 (13.05)

Standard deviations are given in parentheses.

In summary, the behavioral data showed lower acceptability ratings for particle verbs in comparison to prefix verbs. For prefix verbs, sentences with the (finite) prefix verbs in V-second were judged more acceptable than sentences with the (infinitival) verb as part of a fronted VP. The opposite pattern showed up for particle verbs: sentences with the (non-finite) particle verb as part of a fronted VP were judged more acceptable than with the (finite) verb in V-second. This pattern was due to the ungrammaticality of the latter sentences. Therefore, particle verbs in V-second position also showed the lowest acceptability ratings although it appears rather striking that these (presumably ungrammatical) sentences, nevertheless, showed quite a high degree of acceptability. This effect was mainly caused by the responses of three participants who judged more than 85% of these structures as acceptable. In addition, another three participants accepted about 50% of this sentence type, thus indicating that there is an interindividual variance with respect to the acceptability of some of the presented particle verbs in V-second.

2.1.2.2. ERP data. Grand average ERPs at the position of the main verbs and the modal verbs are shown in Fig. 1A and B.

Visual inspection of Fig. 1A indicates a posterior negativity for particle verbs in comparison to prefix verbs. In contrast, at the position of the finite modal verb (Fig. 1B), a posterior negativity is visible for the condition with a preceding prefix verb in comparison to a preceding particle verb. Although both negativities appeared at slightly different latencies, they seemed to have a similar topographical distribution. Note, that the latency difference may have been due to the different word categories (cf. Brown et al., 1999). Therefore, we have chosen different time windows for the statistical analyses of the two positions. Overall, the statistical analyses confirmed our observations.

2.1.2.3. Main verb: N400 time window (400–600 ms). At the position of the main verb, the global ANOVA for the lateral electrodes revealed an interaction of ROI × VERB ($F(3,54) = 15.31$, $p < 0.001$). Separate analyses for each topographical region revealed significant effects of VERB only in the two posterior regions (left-posterior: $F(1,18) = 5.16$, $p < 0.04$; right-posterior: $F(1,18) = 15.46$, $p < 0.001$). The analysis for the midline electrodes showed a main effect of VERB ($F(1,18) = 7.36$, $p < 0.015$) as well as the topographical interaction ROI × VERB ($F(3,54) = 12.51$, $p < 0.001$). Resolving the interaction by ROI revealed significant effects of VERB at Pz ($F(1,18) = 14.48$, $p < 0.002$) and Oz ($F(1,18) = 26.10$, $p < 0.001$). These effects were due to a posterior negativity for particle verbs vs. prefix verbs.

2.1.2.4. Modal verb: N400 time window (350–450 ms). At the position of the finite modal verb, the analysis for the lateral electrodes revealed a main effect of VERB ($F(1,18) = 7.57$, $p < 0.02$) and an interaction of ROI × VERB ($F(3,54) = 4.63$, $p < 0.02$). Resolving the interaction by ROI showed significant effects of VERB in the left-posterior ($F(1,18) = 7.70$, $p < 0.02$) and right-posterior ($F(1,18) = 16.09$, $p < 0.001$) region. The analysis for the midline electrodes showed a main effect of VERB ($F(1,18) = 15.28$, $p < 0.002$) and an interaction ROI × VERB ($F(3,54) = 6.70$, $p < 0.005$). Resolving the interaction by ROI revealed effects of VERB at Cz ($F(1,18) = 9.92$, $p < 0.006$), Pz ($F(1,18) = 19.30$, $p < 0.001$) and Oz ($F(1,18) = 18.49$, $p < 0.001$). These effects were due to a posterior negativity for prefix verbs vs. particle verbs.

In addition to the critical positions of interest to our hypotheses (main verb, modal verb), we also examined the ERPs elicited by the pronoun in the conditions where the subject pronoun immediately followed the main

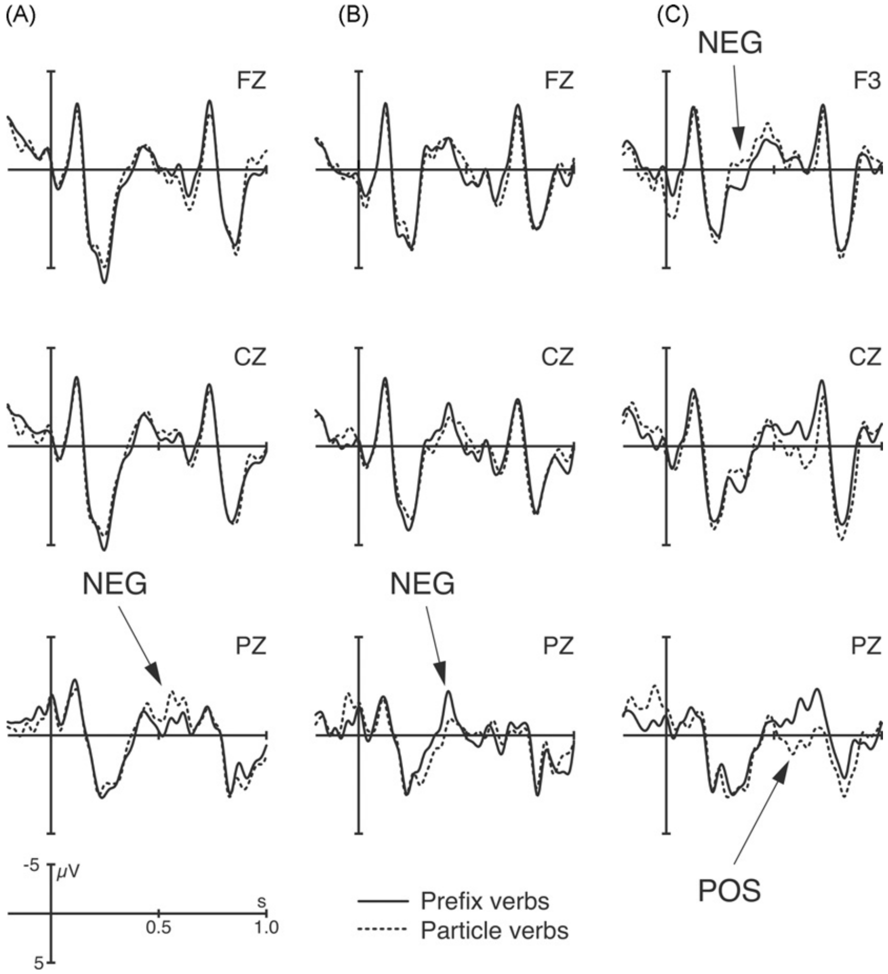

Fig. 1. Grand average ERPs for prefix and particle verbs in Experiment 1 at the position of (A) the main verb, (B) the modal verb, and (C) the pronoun (onset at the vertical bar). Negativity is plotted upwards.

verb (without an intervening modal verb). Grand average ERPs at the position of the pronoun are shown in Fig. 1C. There is an early anterior negativity between approximately 270 and 370 ms post onset of the pronoun as well as late posterior positivity between 500 and 800 ms for the condition with a preceding particle verb in comparison to a preceding prefix verb. The statistical analyses in these time windows confirmed these observations.

2.1.2.5. Pronoun: early negativity time window (270–370 ms). In the early negativity time window, the analysis for the lateral electrodes revealed a main effect of VERB ($F(1,18) = 8.57$, $p < 0.01$) and an interaction of ROI × VERB ($F(3,54) = 3.60$, $p < 0.04$). Resolving the interaction by ROI showed significant effects of VERB in the left-anterior ($F(1,18) = 15.62$, $p < 0.001$) and right-anterior ($F(1,18) = 5.08$, $p < 0.04$) region. The analysis for the midline electrodes showed a significant interaction ROI × VERB ($F(3,54) = 10.32$, $p < 0.001$). Resolving this interaction by ROI revealed effects of VERB at Fz ($F(1,18) = 8.63$, $p < 0.009$) and Cz ($F(1,18) = 7.99$, $p < 0.015$). These effects were due to an anterior negativity for particle verbs vs. prefix verbs, which was slightly more pronounced at left-anterior sites (cf. Fig. 1C).

2.1.2.6. Pronoun: late positivity time window (500–800 ms). For the late positivity time window, the global analysis of the lateral electrodes showed a main effect of VERB ($F(1,18) = 6.95$, $p < 0.02$) as well as an interaction ROI × VERB ($F(3,54) = 10.50$, $p < 0.001$). Resolving the interaction by ROI showed significant effects of VERB in the left-posterior ($F(1,18) = 11.73$, $p < 0.003$) and right-posterior ($F(1,18) = 17.76$, $p < 0.001$) region. The analysis for the midline electrodes showed a similar pattern, namely a main effect of VERB ($F(1,18) = 14.21$, $p < 0.002$) and a significant interaction ROI × VERB ($F(3,54) = 9.05$, $p < 0.001$). Resolving this interaction by ROI revealed effects of VERB at Cz ($F(1,18) = 16.58$, $p < 0.001$), Pz ($F(1,18) = 19.54$, $p < 0.001$) and Oz ($F(1,18) = 14.29$,

$p < 0.002$). These effects were due to a positivity for particle verbs vs. prefix verbs, which had a posterior distribution.[11]

2.1.3. Discussion

Experiment 1 revealed increased processing costs for particle verbs in comparison to prefix verbs at the position of the verb as well as for sentences with prefix verbs in comparison to sentences with particle verbs at the position of the modal verb. In terms of ERP effects, these increased processing difficulties are reflected in an N400-like effect. Importantly, both negativities had a very similar topographical distribution although the N400-like effect for modal verbs had a slightly earlier onset. It has been argued that closed class words are retrieved more rapidly from the mental lexicon than open class verbs thus giving rise to earlier peak onsets (e.g. Brown et al., 1999). We thus suggest that both negativities are an instance of the same type and index the same process, namely, increased processing costs arising because the initial parsing preference is incompatible with the present input string. These findings were expected under the assumption that the parsing preference is based on a Minimal Attachment strategy. After processing the sentence-initial DP the structurally simplest prediction with respect to the subsequent position would be a finite verb in V-second position. In the case of prefix verbs this expectation is fully satisfied. Although inherently ambiguous (on the word-level), the prefix verb is compatible with a finite interpretation as well as the minimal structural position and is thus treated as a saturation of the prediction. It is important to note, that from the perspective of the parser this means that there is no ambiguity at all at the position of the prefix verb. Indeed, we suggest that the parser doesn't even perceive the ambiguity as such. This entails the prediction that there shouldn't be any processing differences between ambiguous and unambiguous prefix verbs as long as both are fully in line with the parser's structural preferences. In contrast to prefix verbs, the particle verbs are (at least partially)[12] incompatible with the parser's prediction. Due to morphosyntactic restrictions (head-movement) the particle cannot be licensed in V-second position (cf. examples in (6)) and, thus, can only be analyzed as part of a fronted VP. This violates the Minimal Attachment preference and gives rise to increased processing costs showing up as a negativity. However, it is unclear whether the increased processing costs are indicative of the conflict arising between the incompatibility of the morphosyntactic information encoded in the particle verb (separability of the prefix) and the parser's predictions (V-second, finiteness), or reflect the cost of reanalyzing the left periphery towards a more complex structure.[13] Either way, the interpretation is in line with the findings at the position of the modal verb. Here the minimality expectation already implemented for prefix verbs needs to be revised at the point the finite modal verb is encountered. For sentences with particle verbs the expectation of a minimal DP-Vfin structure has already been canceled at the position of the verb. Therefore, the finite modal verb is consistent with the minimal prediction resulting from the reanalysis of the DP-particle verb sequence as a fronted VP. Further support for the assumption of a minimality based parsing principle is provided by the findings at the position of the pronoun. There (in the conditions without a preceding finite modal verb) sentences with particle verbs elicited an anterior negativity that was followed by a posterior positivity. This biphasic negativity–positivity pattern strongly resembles an ERP pattern that has repeatedly been found for sentences containing outright violations of a locally predicted word-category (e.g. Neville et al., 1991; Friederici et al., 1993; Hahne and Friederici, 1999). For example, Neville et al. (1991) examined violations such as *Max's of proof the theorem* and observed an (early) left-anterior negativity ((E)LAN) followed by a late positivity at the position of *of*.[14] With respect to the present manipulation we

[11] Note that there were no significant differences between the two verb classes in the late time window (850–1000 ms), neither at the position of the main verb (VERB: $F(1,18) < 1$; ROI × VERB: $F(1,18) = 1.17$, $p > 0.32$; cf. Fig. 1A), nor at the position of the modal verb (VERB: $F(1,18) = 1.61$, $p > 0.22$; ROI × VERB: $F < 1$; cf. Fig. 1B) or the pronoun (VERB: $F(1,18) < 1$; ROI × VERB: $F < 1$; cf. Fig. 1C).

[12] Note that in fact the parser could retain the prediction of finiteness while rejecting the assumption with respect to the structure assignment. We will discuss this issue in the subsequent paragraph.

[13] Evidently, the observed processing costs could be the consequence of rather different processes: they could either be a result of the actual conflict, the problem identification (diagnosis), or the attempt/need to reanalyse. However, for the present discussion these distinctions are not crucial, as long as we treat all of them as immediate consequences of minimality violations. Nonetheless, for the present purposes we assume that the negativity is the reflection of a conflict resulting from the incompatability of two (or more) different information sources.

[14] Note, that strictly speaking the sequence *Max's of* isn't ungrammatical because there are possible continuations such as *Max's of the world* or *Max's of Manila*. However, presented in an experimental setting which included control sentences with possessive proper nouns such as *Max's proof of* ... this reading becomes highly implausible. Therefore it is the unpredictability of the upcoming word in conjunction with the momentary unavailability of an alternative reading which gives rise to the "word-category" violation. Similar arguments apply to the findings of Friederici et al. (1993) and Hahne and Friederici (1999).

presumed that the pronoun constitutes a word-category violation, because according to the parser's most likely prediction a verb (preferentially finite) is expected if the main verb is processed as non-finite. The present ERP findings of an early negativity-late positivity pattern confirm this presumption. We thus conclude that the parser effectively treated the pronoun as an unpredicted word-category (violation) while following structural economy principles. This observation is crucial because it strongly supports the claim that the parser (re)analyzed the initial DP-particle verb sequence as a fronted VP on the basis of morphosyntactic information.

In sum our findings strongly support the assumption that the parser adheres to predictions based on a structural minimality principle such as Minimal Attachment. If structural minimality preferences are violated, increased processing costs arise, which show up as an N400-like effect. However, as already mentioned above, it is not clear whether this effect is an indication of the conflict itself (or it's diagnosis, i.e. predicted information vs. actual information) or of the (structural) revision resulting thereof. Furthermore, an orthogonal problem is the precise source of the processing conflict/revision: (a) for prefix verbs the negativity could either be due to a revision of the finiteness allocation on the prior verb position, when encountering the finite modal verb, thus revealing that the prior verb is not the finite verb; (b) alternatively it could result from the need to revise the structure assignment for the prior verb position, when encountering the finite modal verb, thus revealing that the prior verb is not in the V2-position (i.e. the position of the finite verb, but is the head of a VP in the clause initial position). Since these two aspects are syntactically the two different sides of the same coin, their respective share of the processing costs is hard to factor out. Whereas (a) is a case of early morphosyntactic commitment, (b) is a case of early structural commitment guided by Minimal Attachment. The analog reasoning applies to the processing conflict for particle verbs. Crucially, however, in this case the conflict/revision is not due to a competing finite word but to the incompatibility of the morphosyntactic restrictions (head-movement) with the parser's predictions with respect to finiteness/structural position. This clearly indicates that the parser takes locally available morphosyntactic information into account while pursuing a minimality-based processing strategy.

The finding that the parser's minimality assumptions interact with local morphosyntactic information raises an interesting question: how does the parser deal with morphosyntactic information that clearly indicates the insolubility of an occurring conflict (thus leading to the ungrammaticality of the available structure)? Recall that the N400-like effect in Experiment 1 was caused by minimality violations that could be resolved by restructuring the left periphery of the clause. Therefore, in Experiment 2 we introduced an additional variable that produces an unresolvable conflict situation for particle verbs. In addition, this manipulation allowed us to validate/replicate our findings of Experiment 1.

2.2. *Experiment 2*

The aim of Experiment 2 was to examine how the parser deals with verbs in the left periphery that are unambiguously marked as finite, and thereby – in the case of particle verbs – result in a non resolvable conflict between minimality assumptions and morphosyntactic head-movement restrictions of the particle (thereby leading to ungrammaticality). Thus, we introduced as an additional variable (compared to Experiment 1) the preterite form, since this form codes finiteness unambiguously (cf. 11/12; the two critical regions for the ERP comparisons are underlined). As already emphasized in the introduction, non-separated particle verbs that are explicitly marked as finite are only licensed in sentence final position but not in the left periphery (cf. 12b).[15]

(11) Prefix verbs

a. present	Den Antrag	<u>bearbeiten</u>	<u>alle</u>	selbst.	
	[the application]$_{ACC}$	work-on$_{3.pl.present}$	all$_{3.pl}$	self	
	'All of them work on the application by themselves'				
b. preterite	Den Antrag	<u>bearbeiteten</u>	alle	selbst.	
	[the application]$_{ACC}$	worked-on$_{3.pl.past}$	all$_{3.pl}$	self	
	'All of them worked on the application by themselves'				

[15] Note that (12b) is already ungrammatical at the position of the verb in contrast to (12a). Hence, the pronouns in (11b/12b) are not treated as a critical region for comparison.

c. fronted Den Antrag bearbeiten muss jeder selbst.
[the application]$_{ACC}$ work-on$_{infin}$ must$_{3.sg.present}$ everybody$_{3.sg}$ self
'Everybody must work on the application by himself'

(12) Particle verbs
a. present *Den Katalog abbestellen alle selbst.
[the catalog]$_{ACC}$ de-order$_{3.pl.pres}$ all$_{3.pl}$ self
'The catalog, all of them cancel by themselves'
b. preterite *Den Katalog abbestellten alle selbst.
[the catalog]$_{ACC}$ de-order$_{3.pl.past}$ all$_{3.pl}$ self
'The catalog, all of them canceled by themselves'
c. fronted Den Katalog abbestellen muss jeder selbst.
[the catalog]$_{ACC}$ de-order$_{infin}$ must$_{3.sg}$ everybody$_{3.sg}$ self
'The catalog, everybody must cancel by himself'

This tense manipulation not only produces an unresolvable conflict situation for particle verbs at the position of the verb (12b) but furthermore, provides a neat contrast with the morphologically ambiguous present tense forms of both, prefix and particle verbs. Thus, the preterite form of prefix verbs in comparison with the present tense/infinitival form (11a/b) would show a processing difference if the ambiguous form was not automatically regarded as the finite form. By contrast, in combination with a preceding particle, the preterite form as an explicit finite form signals an irreparable clash to the parser (12b). The same structure with the ambiguous form (12a) allows the parser to restore grammaticality by revising the initially chosen structure assignment towards a clause initial VP (as in 12c). Thus, this contrast allows us to measure the conflict of finiteness in the presence of a particle: either the verb is the finite verb, then the particle is misplaced, or the particle is placed correctly, then the verb must not be finite.

In terms of ERP signatures we expect the following pattern: If ambiguous verbs are initially treated as finite, no difference between ambiguous and non-ambiguous verbs is expected. Hence, the N400-like effects, observed for violations of Minimal Attachment assumptions in Experiment 1, should be the same for conditions with present tense and preterite verb forms. In addition, explicit finiteness (preterite form) leads to an insolvable conflict for particle verbs. We, therefore, expect an additional ERP signature in comparison to the present tense form indexing the ungrammaticality of the string. More precisely, because several previous ERP studies have reported late positivities for the processing of ill-formed structures (e.g. Hagoort et al., 1993; Neville et al., 1991; Osterhout and Holcomb, 1992, 1993; Rösler et al., 1993), we expect a biphasic negativity-late positivity pattern.

2.2.1. Materials and methods

2.2.1.1. Participants. Twenty-one students from the University of Marburg participated in Experiment 2 (13 female, mean age 22.57 (sd = 1.78) years; age range 20–27 years). None of the participants had taken part in Experiment 1. All participants were right-handed, monolingual native speakers of German with normal or corrected-to-normal vision and gave written informed consent before the experimental session. For the ERP analysis, one participant had to be excluded because of excessive EEG artifacts.

2.2.1.2. Materials. Stimulus material was the same as for Experiment 1. In addition, half of the V-second sentences were constructed in past tense thus marking the main verb unambiguously as finite (via the past tense morpheme—*t* as in 11b/12b vs. 11a/12a). In each of the six conditions, forty sentences were presented, thus resulting in a total of 240 critical sentences per experimental session. 160 sentences containing a congruency violation served as fillers. The entire material was assigned to 4 randomized lists of 400 sentences each.

2.2.1.3. Procedure. The procedure was similar to that for Experiment 1. In addition, after a pause of 1000 ms subsequent to the acceptability judgment task, participants were required to complete a probe detection task in order to ensure that they processed the morphological information of the critical verbs. They were presented a probe word which either was part of the previous sentence or not (probes covered all sentence positions). Half of the probes were incorrect.

Table 2
Behavioral results for the acceptability judgment and the probe detection task in Experiment 2

Condition	Acceptability judgment in %	Probe detection in %
Prefix verbs		
V2 present	98.41 (2.06)	99.15 (1.46)
V2 preterite	97.69 (4.17)	99.07 (1.46)
Fronted VP	95.90 (5.11)	98.80 (1.53)
Particle verbs		
V2 present	26.16 (33.99)	97.76 (2.04)
V2 preterite	22.23 (32.96)	97.41 (2.44)
Fronted VP	95.58 (5.57)	99.37 (1.66)

Standard deviations are given in parentheses.

The EEG recording was identical to that for Experiment 1 with the exception that two additional electrodes (O1, O2) were fixed to the scalp, thus resulting in 29 electrode sites.

2.2.1.4. Data analysis. The data analysis was identical to that of Experiment 1 with the exception that trials for which the probe detection task was not performed correctly were excluded. Repeated measures ANOVAs were computed using the condition factors VERB (prefix verbs vs. particle verbs), and TENSE (present tense vs. preterite). Because the present experiment employed an unbalanced design with respect to the factor POSITION, we computed separate ANOVAs for conditions where the main verb was part of a fronted VP and where it was in V-second position.

2.2.2. Results

2.2.2.1. Behavioral data. Mean acceptability ratings for the acceptability judgment task as well as mean percentages of correct answers for the probe detection task are given in Table 2.

For the acceptability ratings of the V-second sentences, a repeated measures ANOVA revealed main effects of VERB ($F_1(1,20) = 102.91$, $p < 0.001$; $F_2(1,78) = 3273.2$, $p < 0.001$) and TENSE ($F_1(1,20) = 6.36$, $p < 0.025$; $F_2(1,78) = 4.80$, $p < 0.035$), and a significant interaction VERB × TENSE for the analysis by subject ($F_1(1,20) = 4.46$, $p < 0.05$; $F_2(1,78) = 1.78$, $p > 0.18$). The resolution of the interaction by VERB revealed a significant difference for particle verbs ($F_1(1,20) = 73.97$, $p < 0.001$; $F_2(1,78) = 3.45$, $p < 0.071$) but not for prefix verbs ($F_1(1,20) < 1$; $F_2(1,78) = 1.83$, $p > 0.18$).

With regard to the probe detection task, the analysis of the error rates revealed a main effect of VERB ($F_1(1,20) = 15.54$, $p < 0.001$; $F_2(1,78) = 9.62$, $p = 0.003$).

The statistical analysis of the conditions with a fronted VP revealed no significant differences between the two verb types, neither for the acceptability judgment task ($F_1(1,20) < 1$; $F_2(1,78) < 1$) nor for the probe detection task ($F_1(1,20) = 1.15$, $p > 0.29$; $F_2(1,78) = 1.72$, $p > 0.19$).

2.2.2.2. ERP-results. Grand average ERPs at the position of the main verbs are shown in Fig. 2A. The visual inspection of the critical ERP comparisons indicated that particle verbs elicited a posterior negativity in comparison to prefix verbs independent of the tense (finiteness) manipulation (cf. Fig. 2A). In addition, there was a late positivity for particle verbs in comparison to prefix verbs, but only when the verb was unambiguously marked as finite via the preterite form (cf. Fig. 2-A2). Moreover, there appeared to be no difference between the two prefix verb conditions.

The statistical analysis for the two time windows mostly confirmed the observations.

2.2.2.3. Main verb: N400 time window (400–600 ms). At the position of the main verb, the global ANOVA for the lateral electrodes revealed a main effect of VERB ($F(1,19) = 10.25$, $p < 0.005$) as well as the interactions of ROI × VERB ($F(3,57) = 5.41$, $p < 0.005$) and VERB × TENSE ($F(1,19) = 7.88$, $p < 0.015$). Resolving the interaction by ROI revealed significant effects of VERB in the left-posterior ($F(1,19) = 11.61$, $p < 0.003$) and right-posterior region ($F(1,19) = 28.69$, $p < 0.001$). The resolution of the interaction VERB × TENSE by verb type showed no significant effect for particle verbs ($F(1,19) = 2.26$, $p > 0.14$). In contrast, there was a significant difference between prefix verbs in present tense and preterite ($F(1,19) = 4.46$, $p < 0.05$). Notably, this effect was entirely due to a

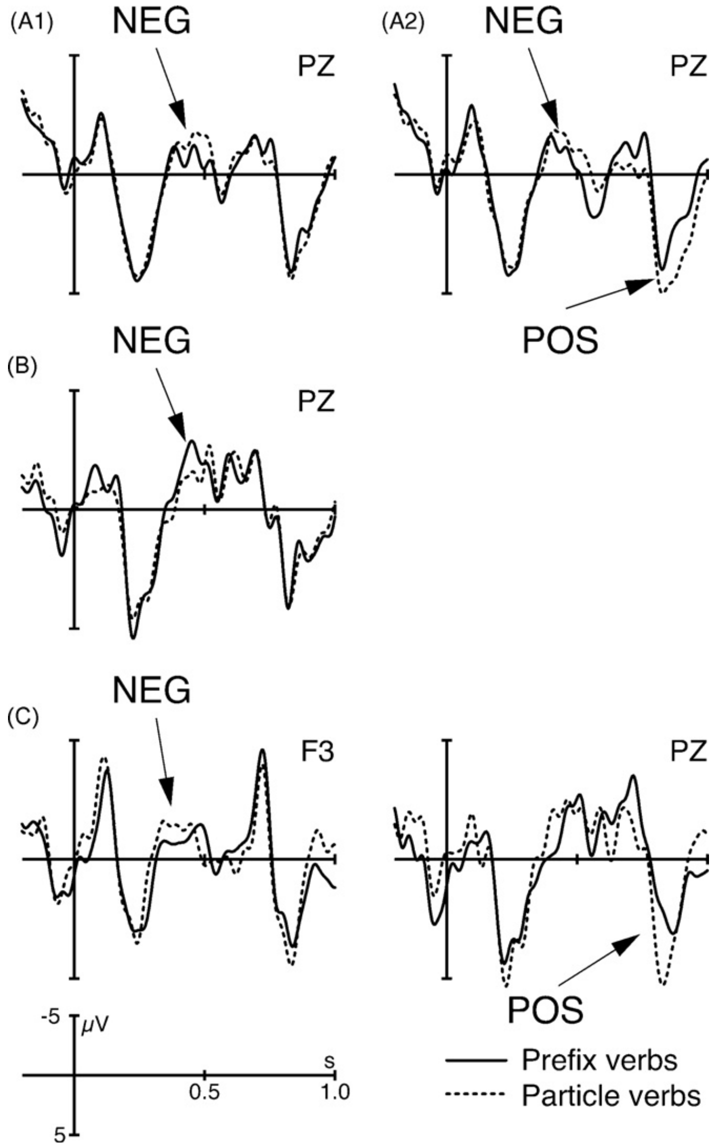

Fig. 2. Grand average ERPs for prefix and particle verbs in Experiment 2 at the position of the main verb (A) for ambiguous (A1), and unambiguous verbs (A2), at the position of the modal verb (B), and at the position of the pronoun (C; onset at the vertical bar). Negativity is plotted upwards.

temporally very localized positive shift in the time window between 550 and 600 ms. Analyzing the shorter N400 time window 400–550 ms revealed neither a significant interaction VERB × TENSE ($F(1,19) = 2.08$, $p > 0.12$) nor a difference between the two prefix verbs ($F(1,19) = 2.49$, $p > 0.13$), but, nevertheless, a significant effect of VERB ($F(1,19) = 7.41$, $p < 0.015$) and ROI × VERB ($F(3,57) = 5.33$, $p < 0.007$).

The analysis for the midline electrodes showed a main effect of VERB ($F(1,19) = 22.47$, $p < 0.001$) and the interaction ROI × VERB ($F(3,57) = 5.12$, $p < 0.02$). Resolving the interaction by ROI revealed significant effects of VERB at Cz ($F(1,19) = 16.57$, $p < 0.001$), Pz ($F(1,19) = 39.09$, $p < 0.001$) and Oz ($F(1,19) = 31.67$, $p < 0.001$). These effects were due to a posterior negativity for particle verbs vs. prefix verbs.

2.2.2.4. Main verb: late positivity time window (650–900 ms). The global analysis for the late positivity time window for lateral electrodes revealed main effects of VERB ($F(1,19) = 4.87$, $p < 0.04$) and TENSE ($F(1,19) = 6.20$, $p < 0.025$) as well as the interactions ROI × VERB ($F(3,57) = 14.81$, $p < 0.001$), ROI × TENSE ($F(3,57) = 5.12$, $p < 0.015$), and ROI × VERB × TENSE ($F(3,57) = 8.36$, $p < 0.001$). Resolving the latter interaction by ROI revealed significant effects only for the two posterior regions. Both regions showed main effects of VERB (left-posterior: $F(1,19) = 14.91$, $p < 0.002$; right-posterior: $F(1,19) = 39.18$, $p < 0.001$), TENSE (left-posterior: $F(1,19) = 9.75$, $p < 0.006$; right-posterior: $F(1,19) = 6.34$, $p < 0.025$), as well as an interaction VERB × TENSE (left-posterior: $F(1,19) = 8.78$, $p < 0.008$; right-posterior: $F(1,19) = 7.07$, $p < 0.02$). Planned comparisons by VERB revealed significant effects of TENSE for particle verbs (left-posterior: $F(1,19) = 12.32$, $p < 0.003$; right-posterior: $F(1,19) = 11.56$, $p < 0.003$) but not for prefix verbs (left-posterior: $F(1,19) < 1$; right-posterior: $F(1,19) < 1$).

The analysis for the midline electrodes showed a main effect of VERB ($F(1,19) = 22.08$, $p < 0.001$) and the interactions ROI × VERB ($F(3,57) = 11.77$, $p < 0.001$) and VERB × TENSE ($F(1,19) = 12.80$, $p < 0.002$). Resolving the latter interaction by VERB only revealed a significant effect of TENSE for particle verbs ($F(1,19) = 9.46$, $p < 0.007$) but not for prefix verbs ($F(1,19) < 1$). These effects were due to a posterior positivity for particle verbs that were unambiguously marked as finite.

At the position of the modal verb (Fig. 2B) there was a posterior negativity for sentences with a preceding prefix verb in comparison to particle verbs, thereby replicating the finding of Experiment 1.

2.2.2.5. Modal verb: N400 time window (350–450 ms). The analysis for the lateral electrodes revealed an interaction of ROI × VERB ($F(3,57) = 7.69$, $p < 0.001$). Resolving this interaction by ROI showed significant effects of VERB in the left-posterior region ($F(1,19) = 10.26$, $p < 0.005$). The analysis for the midline electrodes only showed a marginal main effect of VERB ($F(1,19) = 3.97$, $p = 0.060$). These effects were due to a left-lateralized posterior negativity for prefix verbs vs. particle verbs.[16]

As in Experiment 1, we examined the ERPs elicited by the pronoun in the conditions with a main verb in the present tense form (cf. Fig. 2C). Like in Experiment 1, there was an early negativity followed by a late posterior positivity for pronouns immediately preceded by a particle verb (in comparison to prefix verbs). The statistical analyses in these time windows confirmed these observations.

2.2.2.6. Pronoun: early negativity time window (340–440 ms). In the early negativity time window, the analysis for the lateral electrodes revealed a main effect of VERB ($F(1,19) = 5.69$, $p < 0.03$), and an interaction ROI × VERB ($F(3,57) = 4.55$, $p < 0.009$). Resolving the interaction by ROI revealed significant effects of VERB in the posterior regions (left-posterior: $F(1,19) = 21.49$, $p < 0.001$; right-posterior: $F(1,19) = 6.68$, $p < 0.02$). The analysis for the midline electrodes showed a main effect of VERB ($F(1,19) = 9.37$, $p < 0.007$) and the interactions ROI × VERB ($F(3,57) = 3.10$, $p < 0.05$). Resolving the interaction by ROI revealed significant effects of VERB at Cz ($F(1,19) = 6.80$, $p < 0.018$), Pz ($F(1,19) = 14.67$, $p < 0.002$) and Oz ($F(1,19) = 13.72$, $p < 0.002$). These effects were due to a negativity for particle verbs vs. prefix verbs.

2.2.2.7. Pronoun: late positivity time window (600–900 ms). For the late positivity time window, the global analysis of the lateral electrodes showed a main effect of VERB ($F(1,19) = 8.15$, $p < 0.015$), as well as an interaction ROI × VERB ($F(3,57) = 9.68$, $p < 0.001$). The resolution of this interaction by ROI revealed significant effects of VERB in the posterior regions (left-posterior: $F(1,19) = 18.75$, $p < 0.001$; right-posterior: $F(1,19) = 16.05$, $p < 0.001$). The analysis for the midline electrodes showed a main effect of VERB ($F(1,19) = 15.97$, $p < 0.001$) and an interaction ROI × VERB ($F(3,57) = 5.09$, $p < 0.015$). Resolving the interaction by ROI revealed significant effects of VERB at Cz ($F(1,19) = 11.27$, $p < 0.004$), Pz ($F(1,19) = 22.32$, $p < 0.001$) and Oz ($F(1,19) = 24.87$, $p < 0.001$). As for Experiment 1, these effects were due to a posterior positivity for particle vs. prefix verbs.

Note that, in addition to the effects replicated from Experiment 1, there was a significant main effect of VERB ($F(1,19) = 9.39$, $p < 0.001$) in the late time window (900–1000 ms) that was due to a pronounced negativity for the condition with particle verbs. Crucially, this effect appeared ~300 ms after the onset of the sentence-final adverbial adjunct. Because it is well-known that apart from local effects, sentence-final words are often strong attractors of global processing factors related to sentence wrap-up, decision, and response requirements (Schriefers et al., 1995), we believe that the present negativity is an instance of an N400-like effect which previously has been reported for sentence final words in sentences that subjects judge as unacceptable (Hagoort et al., 1993; Osterhout and Holcomb, 1992, 1993).

[16] Like in Experiment 1, there was no significant difference between the two verb classes in the 850–1000 ms time window (VERB: $F(1,18) = 3.65$, $p > 0.07$; ROI × VERB: $F < 1$; cf. Fig. 2A). The slight tendency in the late time window was entirely due to some vertical eye movements in the postcritical region (position of the pronoun). Hence, after rescanning the EEG of four participants and the removal of trials with residual eye-artefacts there was no more indication of any difference (VERB: $F < 1$; ROI × VERB: $F < 1$).

2.2.3. Discussion

Essentially, Experiment 2 replicated the three findings from the first experiment: (a) for verbs in present tense there was an N400-like effect for particle verbs in comparison to prefix verbs at the position of the main verb; (b) for sentences with the infinitival main verb as part of the fronted VP, there was an N400-like effect at the position of the modal verb for the condition with prefix verbs in comparison to particle verbs; (c) at the position of the pronoun sentences with particle verbs in present tense elicited a negativity which was followed by a posterior positivity. Note that the biphasic ERP pattern for the pronoun had a latency shift of about 70 ms in comparison to Experiment 1. This latency difference most likely was due to a small difference in the stimulus material: whereas in Experiment 1 the post-verbal NP-position always was filled with the unbound pronoun *sie* 'they', Experiment 2 comprised quantifiers such as *manche* 'some', *viele* 'many', *alle* 'all', or *einige* 'few'. Therefore, the latency difference might be attributed to differences in word length and frequency (for instance, it has been shown that short words elicit earlier ERP responses than long words; e.g. Osterhout et al., 2002).

Taken together, these findings, thus, confirm the validity and reliability of the results from Experiment 1. Even more important are the results from the added preterite manipulation. Although an input string with particle verbs in the preterite form (in V-second position) is straightforwardly ungrammatical, there was no difference in the N400 time window between the preterite and present tense form of the particle verb. Both conditions showed an N400-like effect in comparison to prefix verbs. This clearly indicates that the parsers initial structural commitment based on Minimal Attachment preferences is not blocked despite the availability of explicit finiteness information rendering the input sequence apparently ungrammatical. The mismatch between morphosyntactic head-movement constraints and the parser's predictions with respect to finiteness/structural position is, thus, the same for both conditions (independent of the directness of the finiteness information). Though, whereas in the case of particle verbs in present tense there is an accessible alternative structure, there is no possibility to resolve the conflict in the case of the preterite form. The resulting failure in well-formedness/repair is reflected in a late positivity for the preterite form.

The hypothesis of a minimality-based structural predictive processing strategy is further corroborated by the findings for the prefix verbs. Although, the statistical analysis suggested a significant difference between ambiguous and unambiguous verb forms, a closer inspection revealed that this effect was entirely driven by a temporally rather restricted positivity for the unambiguous condition in the post-N400 time range (550–600 ms). It is a well-known finding from so-called oddball paradigms (e.g. Johnson and Donchin, 1980; Polich, 1987) that low probability stimuli in comparison to high probability stimuli yield an enhanced P300 amplitude. Furthermore, the P300 amplitude is not only dependent on the objective probability with which a stimulus appears, but also on its task relevance. Because the present stimulus material comprised twice as much verb forms in present tense than in preterite, we presume that the observed positivity for preterite prefix verbs is an instance of an P300 effect (which is obscured for preterite particle verbs due to component overlap in the same time window; cf. Roehm et al., 2007). Crucially, however, there was no difference in the narrower N400 time window (400–550 ms) between (ambiguous) present tense and (unambiguous) preterite prefix verbs. This clearly indicates, that the parser treated the present tense verb form, although inherently ambiguous, not as ambiguous at all. Thus, independent of whether the verb was explicitly marked with finiteness features the parser assigned a minimal V-second structure on the basis of structural minimality preferences.

3. General discussion

All in all, our present findings clearly demonstrate that explicit morphosyntactic indicators (finiteness/particle separability) are taken into account by the parser insofar they provide information which is *incompatible* with the parser's predictions built on the basis of a structural minimality heuristic.[17] When the input string is ambiguous or underspecified the parser proceeds according to his minimality-based preferences. Thus, from the perspective of the incremental parser, ambiguities are not obvious as such (and therefore do not have to be resolved). Such a view strongly contradicts parallel approaches to sentence parsing which assume that the parser is sensitive to ambiguous

[17] Note that the preference for a finite over a non-finite verb reading probably could also be explained on the basis of frequency distributions (e.g. in terms of local transition probabilities) because verbs are overwhelmingly finite when they occur after a sentence-initial DP. Under such an account frequency and not minimality would be considered as the cause of the observed N400 effects. However, the data pattern as a whole cannot be explained entirely on the basis of frequency distributions and, therefore, it seems rather unlikely that frequency is the crucial driving force.

material. Therefore, they predict that the processing of ambiguous structures should lead to enhanced processing costs compared to unambiguous ones, at least locally (Altmann and Steedman, 1988). On the other hand, serial models predict that an ambiguous structure should be equally easy to process as its simplest unambiguous counterpart (Frazier, 1987; Lewis, 2000; Mitchell, 1994). The results from Experiment 2 revealed that there were no obvious processing costs for the verb inherent ambiguity (likewise, for prefix and particle verbs), thus, clearly supporting serial models of sentence processing.[18]

Furthermore, the claim that the parser might be unaware of an ambiguity during parsing entails that while stumbling across conflicting information he is challenged to identify the actual source of the apparent conflict in order to resolve it.[19] Whereas the source of the conflict is generally assumed to lie in the actual (structural) ambiguity and therefore in the parsers 'wrong' decision with respect to its resolution, the nature of the conflict can be manifold. However, the crucial point is that if the ambiguity is not obvious to the parser during incremental parsing (as we argued above), the identification of the problem's source as well as its actual nature becomes vague (if not impossible). Yet, reanalysis can only be successfully accomplished if the source can be reasonably localized. Intuitively, localization should become the more difficult the farther the actual source of the misparse is from the encountered conflict. Indeed, it has been shown that the processing of garden-path sentences is harder when lexical material intervenes between the disambiguator and the head of the ambiguous phrase (Ferreira and Henderson, 1991). In contrast, if the ambiguity source cannot be retrieved at all the parser adheres to its previous decisions and regards the encountered material as ungrammatical.[20]

Our present manipulations involved an ambiguity that was locally identifiable by means of the resulting conflict. That is, for both verb types the induced minimality violation comprised a *local* conflict. For prefix verbs the conflict arises between two adjacent verbs (prefix verb and modal verb) competing for finiteness as well as for structural position. Because only one of the two competing verbs was explicitly marked as finite, the parser's early commitment was revisable by backtracking to an alternative syntactic structure. In this way, the observed N400-like effect can be regarded as a reflection of the diagnosis of the actual (syntactic) conflict. By contrast, for particle verbs the conflict arises *word-internally* as a conflict between presumed (Experiments 1 and 2) or explicit (Experiment 2) finiteness and morphosyntactic restrictions with respect to the particle (head-movement). Again, the source of the conflict was retrievable via the diagnosis of the conflict that in turn required a structural reanalysis. If the conflict was unresolvable like in the case of explicitly finite marked particle verbs (Experiment 2) the resulting ungrammaticality led to an additional late positivity (P600).

Based on these considerations we suggest that conflict identification (diagnosis) is linked to the appearance of an N400, and a resulting ungrammaticality to a late positivity (P600). Crucially, the conception that the present N400 is not a reflection of conflict resolution (reanalysis) per se but indeed denotes conflict identification (diagnosis) – whereas the late positivity is indicative of the failure of reanalysis – presupposes that there are no obvious ERP effects that can be regarded as processing cost for the actual necessary structural revisions. More precisely, this implies that the accomplished structural reanalysis (of the V2 structure) is cost-free. Such a position (no repair costs), in fact, is advocated in the approach of Fodor and Inoue (1998, 2000). Evidently, the findings from Experiment 2 for particle verbs support the hypothesis that the N400 reflects diagnosis rather than reanalysis. Both, present tense and preterite verbs showed no difference with respect to the N400. Yet, if the N400 would reflect reanalysis per se, one would expect differences between the two verb forms: because the latter comprises an obvious unresolvable conflict processing costs should either be higher (due to an increased effort to solve the conflict) or lower (due to abandonment of processing) in comparison to the former.

[18] On the basis of an ERP study Frisch et al. (2002) claimed that their results speak in favour of parallel models of syntactic processing. They reported an P600 for case ambiguous vs. unambiguous initial noun phrases in German sentences. However, because all sentences were transitive and only sentences with ambiguous initial noun phrases comprised syntactic function ambiguities, half of which caused syntactic reanalyses towards a dispreffered object–subject order (at the position of the second argument), it is more likely that the observed positivity was an instance of a task-related P300 (indexing the probability/likelihood of upcoming processing difficulties). Such an explanation is further corroborated by studies finding no effects for sentence initial case ambiguities (e.g. Hopf et al., 1998).

[19] It is clear that the identification of the source of the conflict (where does the problem come from; where is the ambiguity) and the nature of the conflict (what is the problem) are not independent from each other. Proper insight into the nature of the conflict presumes identification of the causative problem/ambiguity. Conversely, the problem source might be retrievable if the conflict's nature is fully transparent.

[20] This is most likely the case in severe garden path sentences (Fodor and Inoue, 1998).

Strikingly, our present findings of an N400 are in sharp contrast to previous findings that report an P600 in response to minimality violations. For example, Osterhout (1997) investigated sentences with RRCs of the type *The boat sailed down the river sank (. . .)*. In comparison to a control sentence (*The boat sailed down the river and sank* . . .) they found a P600 effect at the position of *sank* in the RRC-condition. This is the position where the sentence becomes ungrammatical when the parser follows a structural minimality heuristic and analyses the verb *sailed* as a simple active verb. One could be tempted to argue that the source of the conflict (the ambiguity) is not easily retrievable, and therefore reanalysis might be so difficult that the sentence is regarded as ungrammatical thus leading to a late positivity (as in the case of syntactic anomalies which comprise outright violations of syntactic structures). Yet, such an oversimplified view is not warranted in the light of other ERP-findings from studies of syntactic ambiguities. Osterhout and Holcomb (1992, 1993) investigated MV/RRC-ambiguities of the type *The dancer tried/encouraged to join the ballet (was talented in music)*. Whereas the clausal complement *to join the ballet* can be easily attached to the intransitive verb *tried*, the transitive verb *encouraged* (in its active form) does not allow an argument beginning with the word *to* immediately adjacent to the verb. Instead, the sequence *encouraged to* has to be reanalyzed as passivized RRC. The observed processing difficulty was rather weak and the correct reduced relative reading could be readily retrieved (as indicated by the ease in which the subsequent word string *was talented* could be attached as the main predicate of the clause).[21] Nonetheless, Osterhout and Holcomb found a widely distributed P600 at the position of *to* for sentences with transitive in comparison to intransitive verbs. Furthermore, similar P600s have been observed in NP-S ambiguities like *The judge believed the defendant was lying* (Osterhout et al., 1994). As for the morphosyntactic conflicts investigated in the present experiments, the critical words (*to/was*) inducing the integration difficulty are adjacent to the actual source of the conflict (the misparsed transitive verb). This allows an easy retrievability of an alternative parse (thus resulting in only a mild garden-path). Overall, it appears that the P600 is more likely linked to the diagnosis of the actual conflict source.[22] This, however, leads to a rather paradoxical situation: if both, the P600 and the N400 observed in the present experiments, reflect the putative same processing mechanisms, how come that they show up as different ERP components? Yet, a closer look at the respective structural ambiguities and their required structural reanalysis reveals that there might be a straightforward resolution to this impasse. Although in all cases the conflict is rooted in a mismatch between minimality-based predictions of the parser and the actual input string, there are fundamental differences in the complexity of the necessary restructuring. In the one case (e.g. for MV/RRC or NP-S) reanalysis either involves a restructuring across a sentence boundary from a single towards a more complex clause structure (i.e. the ambiguous element has to be reanalyzed as part of a second, namely, embedded clause) or a restructuring across a sentence boundary within a complex clause (e.g. for relative clause attachment ambiguities where an P600 has been observed independent of whether the actual attachment is low (as in English; cf. Kaan and Swaab, 2003b) or high (as in Spanish; Carreiras et al., 2004)). In the other case (i.e. for the present ambiguity type) it merely requires a syntactic restructuring within a single clause.

We thus can break down the apparent differences into a simple metric: restructuring towards or across a nested/biclausal sentence structure results in a P600, restructuring within a monoclausal structure leads to a negativity.[23] Remarkably, Osterhout (1997) reports that a small subset of subjects didn't show a P600 in response to MV/RRC-ambiguities, but an N400 instead (presumably indicating semantic integration problems). This, however, is not surprising under the present assumptions: if the problem source is not uniquely identifiable, variance with respect to individual processing strategies (conflict treatment) is expected. Such a subject-specific strategic behavior has also been shown for the processing of violations of semantic (antonym) relations (Roehm, 2004; Roehm et al., 2007).

[21] This is also indicated by the relatively high acceptability ratings (80%) of the whole sentence *The dancer encouraged to join the ballet was talented in music*; Osterhout and Holcomb (1992:794).

[22] This view of the P600, however, presupposes that there are (at least two) different types of late positivities: one for structures which are recoverable and allow a structural reanalysis (e.g. in the case of violations of a syntactic preference), and one for ungrammatical structures (e.g. where syntactic anomalies include outright violations of an obligatory syntactic structure). For a similar proposal cf. Friederici et al. (2002).

[23] Recent findings of Kaan and Swaab (2003a) can be regarded as further evidence for such a view. They investigated NP-S conjunction ambiguities (such as *The man is painting the house and the garage is already finished*) which require the reinterpration of the *and*-conjunct (*the garage*) as the subject of a conjoined clause at the position of the second auxiliary (*is*). Crucially, in comparison to unambiguous parallels (*The man is painting the house but the garage is already finished*) they found a negativity at the position of *is* (followed by a task-dependent P600) indicating a simple reanalysis of the misparsed sentence structure (detach the conjunction and open up a new conjoined clause).

4. Conclusion

To sum up, the present study examined the role of the parser's behavior with respect to the prediction of minimal structures and the interplay of morphosyntactic information during incremental syntactic processing. The present ERP findings not only provide clear evidence for minimality preferences in structure assignment (assign the minimal structurally convergent structure for the given input) but also for the immediate validation of the minimality assumptions, based on locally available information stemming from finiteness morphology (see preterite data) as well as from morphosyntactic head-movement restrictions ('leave the particle behind when you place the finite verb in the fronted position'). More specifically, we propose that the observed ERP pattern – which is contradictory to previous ERP findings for structural ambiguities – is a direct reflection of reanalysis happening within a single clause without crossing clause boundaries. This finding points towards a simple metric which is solely dependent on the complexity of structural reanalysis: that is, whether the required structural modification proceeds within a single clause, or takes place across a sentence boundary.

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