

# The morphosyntactic decomposition and semantic composition of German compound words investigated by ERPs

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## Abstract

In two experiments, we investigated the morphosyntactic decomposition and semantic composition of acoustically presented German compound words. A left-anterior negativity (LAN) was found in the ERP for gender incongruent, initial compound constituents although these constituents are syntactically irrelevant in German. This LAN provides online evidence for morphosyntactic decomposition. Experiment 1 showed also preliminary evidence for semantic composition, which was further investigated in Experiment 2 by comparing semantically transparent and opaque compounds. Transparent compounds elicited an increased negativity with a centroparietal maximum that occurred during the presentation of the head constituent. This negativity is suggested to reflect the semantic integration of compound constituents that is necessary after the constituents have been accessed separately.

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## 1. Introduction

Much psycholinguistic research has focused on the question whether morphologically complex words are stored in the mental lexicon in their full form or whether only their morphemes are stored and combined to process complex word forms. The former idea is proposed by so-called full-listing models (e.g., Butterworth, 1983; Bybee, 1995). The latter view, that only morphemes are stored, is suggested by full-parsing models (e.g., Libben, Derwing, & de Almeida, 1999; McKinnon, Allen, & Osterhout, 2003; Taft, 2004; Taft & Forster, 1976). These models can be contrasted with another class of models, namely dual-route models which assume two processing routes. According to dual-route models, a complex word can either be stored completely or be decomposed into its morphological constituents (Baa-

yen, Dijkstra, & Schreuder, 1997; Caramazza, Laudanna, & Romani, 1988; Isel, Gunter, & Friederici, 2003; Sandra, 1990; Schreuder, Neijt, Van der Weide, & Baayen, 1998; Zwitserlood, 1994). For example, very frequently used compounds (e.g., “airport”) and opaque ones (e.g., “butterfly”) are supposedly stored in their full form. For very frequently used ones storage is more efficient than repeated composition, and the meaning of opaque compounds cannot be derived from their constituents (cf. Sandra, 1994). In contrast, novel compounds (e.g., “butter port”) would be decomposed and their constituents’ meaning needs to be combined.

In order to decide among these models, many studies have been concerned with semantic decomposition of compounds in the auditory and visual modality (Coolen, Van Jaarsveld, & Schreuder, 1993; Isel et al., 2003; Jarema, Busson, Nikolova, Tsapkini, & Libben, 1999; Libben, 1993; Pratarelli, 1995; Sandra, 1990; Wagner, 2003; Zwitserlood, 1994). In addition to semantic decomposition, morphological decomposition has also been reported in reaction time

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(Andrews, 1986; Caramazza et al., 1988; Jarema, Libben, Dressler, & Kehayia, 2002; Taft & Forster, 1976; Zwitserlood, 1994) and eye-tracking studies (Hyönä & Pollatsek, 1998; Juhasz, Starr, Inhoff, & Placke, 2003). Typically, these studies report decomposition effects which are in accordance with full-parsing and dual-route models but not with full-listing models.

Less is known about morphosyntactic decomposition and semantic composition. Semantic composition refers to the integration of constituents' meaning that is crucial once constituents have been accessed separately, i.e. after decomposition. Event-related potentials (ERPs) with their high temporal resolution are a suitable tool to investigate such fast psycholinguistic processes, and some ERP studies examined morphosyntactic (decomposition) processes in the realm of inflection (e.g., Gunter, Stowe, & Mulder, 1997; Lavric, Pizzagalli, Forstmeier, & Rippon, 2001; Münte, Say, Clahsen, Schiltz, & Kutas, 1999; Penke et al., 1997; Weyerts, Penke, Dohrn, Clahsen, & Münte, 1997). In contrast to this, only few ERP studies have been devoted to compound words. These studies which were carried out in the auditory modality reported evidence that supports semantic decomposition (Pratarelli, 1995; Wagner, 2003) as well as evidence in favour of morphosyntactic decomposition (Koester, Gunter, Wagner, & Friederici, 2004).

In our previous study (Koester et al., 2004), we used the morphosyntactic feature gender to investigate morphosyntactic decomposition in compounds. Gender can establish coherence within and across sentences via agreement between language elements such as adjectives, numerals, and nouns (Corbett, 1991). In German, gender classifies nouns into three classes (masculine, feminine and neuter) and needs to agree, for example, between determiner and noun. Gender violations have been shown to elicit a left-anterior negativity (LAN) between 300 and 500 ms after stimulus onset followed by a P600 (Deutsch & Bentin, 2001; Gunter, Friederici, & Schriefers, 2000, but see Hagoort & Brown, 1999; Schmitt, Lamers, & Münte, 2002). In Koester et al. (2004) we manipulated the gender agreement between a definite determiner and the constituents of opaque and transparent two-constituent compounds. For gender violations of initial constituents we found only a LAN. Such a LAN can be taken as an index of a gender violation detection and, thus, of morphosyntactic decomposition. Importantly, the LAN was observed for both opaque and transparent compounds.

This result argues for a dual-route model with parallel processing routes (e.g., Caramazza et al., 1988; Isel et al., 2003). If decomposition takes place only after a full word form match failed, only transparent compounds should be decomposed because opaque ones have a lexical entry and can be found in a full word form search. Accordingly, a LAN would be expected only for transparent but not for opaque compounds. However, this was not attested by the data (Koester et al., 2004). The absence of a P600 may indicate that the disagreement is not reanalysed or repaired

(Friederici, 2002). This is plausible because initial constituents are syntactically irrelevant in German (Fleischer & Barz, 1995) and the P600 is susceptible to controlled processes (Hahne & Friederici, 1999).

In the auditory modality, compound constituents are perceived serially and it is known that (onset) embedded words receive some activation during the time course of presentation (for a recent review McQueen, 2005; Zwitserlood, 1989). This may suggest that the single noun corresponding to a compound's initial constituent is activated because it overlaps phonologically with the compound constituent. However, initial compound constituents differ from the same words spoken as single nouns in at least two prosodic parameters: duration and fundamental frequency (Isel et al., 2003; Koester et al., 2004; Vogel & Raimy, 2002). That is, on the basis of prosodic cues the language processing system (*parser*) can distinguish single nouns and compounds. Furthermore, it was shown that prosodic cues influence the parsing of compounds (Isel et al., 2003; Koester et al., 2004). This suggests that the parser can process initial constituents in another way than single nouns.

The purpose of the first experiment was to replicate the LAN for initial constituents as reported in Koester et al. (2004) with different subjects and materials, namely novel three-constituent compounds. Because the previously observed LAN was of a small magnitude, it is important to show that the LAN is independent of the materials. The small magnitude of the LAN might be explained by the fact that the stimuli were minimal phrases (determiner + compound). In sentences, however, gender violation effects might be augmented by non-linguistic factors, e.g., by instructions to correct errors or attention. We argue that for gender violation detections the magnitude of an effect is of secondary importance because gender agreement is binary (agreement vs. violation); based solely on syntactic gender agreement, graded modulation cannot be expected.

In Experiment 1, we used novel three-constituent compounds that were presented acoustically. The gender agreement of initial and head constituents was manipulated and we expected a LAN for both constituents if they are gender incongruent.

## 2. Experiment 1—morphosyntactic decomposition

### 2.1. Materials and methods

#### 2.1.1. Subjects

A total of 30 (15 male) right-handed German native speakers (18–30 yrs; mean 24; 5 yrs) were paid for their participation. They had normal or corrected to normal visual acuity and normal hearing.

#### 2.1.2. Materials

We constructed novel German compounds consisting of three constituents (nouns) for presentation together with a definite determiner (e.g., “der Stahlhakenpreis,”

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