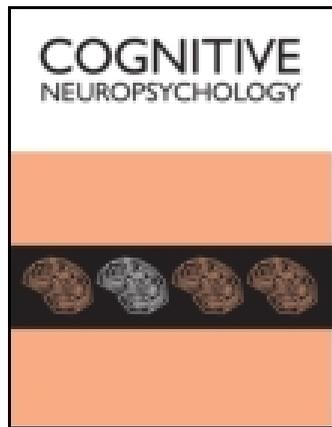


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Combining words in the brain: The processing of compound words. Introduction to the special issue

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Combining words in the brain: The processing of compound words

Introduction to the special issue

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WHY DO COMPOUNDS DESERVE SPECIAL INTEREST?

Why devote special attention to compound words? Compound words are not marginal linguistic elements of the lexicon: They reflect very important processes, and they are interesting in several respects. Combining words to obtain another word is, undeniably, a fundamental ability of our minds.

It has been argued that compounding was one of the first processes to appear when language first developed: Jackendoff (2002), for example, has claimed that compounds may indeed be “protolinguistic fossils” from which more complex linguistic structures have developed. Compound words imply specific syntactic processes; in terms of the minimalist programme (Chomsky, 2001) they may be seen (Mukai, 2013) as the result of a simple instance of “merge”, one of the basic operations when two syntactic objects are combined to form a new syntactic unit. Compounds are indeed very interesting linguistic elements because composition is a very productive way to increase the size of the vocabulary. However, in

this respect composition may work differently in different languages: For instance, in Germanic languages and in Finnish, composition is a very productive—almost syntactic—process that allows a recursive and substantially unlimited noun–noun modification (e.g., the German compound noun *Hallenhandballweltmeisterschaft*, hall handball world championship). On the contrary, in Romance languages composition is an essentially frozen—that is, nonproductive—process, with the consequence that only a relatively small number of noun–noun compounds (and only lexicalized compounds) exist in these languages (although some productivity occurs, for verb–noun nominal compounds—e.g., the French noun *portemanteau*, coat hanger, literally: “carries coat”¹). Another source of diversity in composition concerns the position of head and modifier across languages. In Germanic languages, the head of a compound is always the final element of the word chain, in Hebrew it is always the initial element (e.g., *ugat shokolad*, chocolate cake, literally: cake chocolate), while in Italian, both conditions are possible (e.g., *astronave*, starship, head-final, vs. *pescespada*, swordfish, literally: fish sword, head-initial).

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¹ French and Italian verb–noun nominal compounds are exocentric, i.e. neither the verb nor the noun constituent is the lexical or semantic head of the compound.

THE PROCESSING OF COMPOUNDS

Whether compounds—and morphologically complex words more generally—are processed as wholes or through their morphological constituents has been matter of debate for the last 30 years. On the one hand, full-listing hypotheses (e.g., Butterworth, 1983) suggest a single whole-form representation for complex words. On the other hand, full-parsing models (e.g., Taft & Forster, 1976) posit automatic parsing and independent access to the constituent morphemes of complex words.

However, neither of these alternative accounts is fully consistent with experimental data, and dual-route models of processing have been proposed in which lexical access for complex words is based on both a whole-word and a parsing procedure (Pollatsek, Hyönä, & Bertram, 2000; Schreuder & Baayen, 1995). The mechanisms underlying dual-route processing of morphologically complex words is still under debate. The early version of the dual-route account proposed that both parsing and whole-word processing of morphologically complex words run in parallel, and that the efficiency of either procedure is governed by word frequency effects: For high-frequency complex words whole-word access is dominant, whereas low-frequency complex words are likely to be parsed when their constituents are high-frequency morphemes. More recent versions of the dual-route account (multiroute models) depict lexical processing as a flexible and cooperative procedure that relies on information from both the compound as a whole and its constituents starting from the earliest stages of complex word identification (e.g., Kuperman, Schreuder, Bertram, & Baayen, 2009). Moreover, the effects of the first and second constituents are not always equal and suggest a dominant role of either the second (Juhász, Starr, Inhoff, & Placke, 2003) or the first constituent (Hyönä and Pollatsek, 1998) in accessing the whole compound.

The above proposals mostly focus on the lexical aspects of word processing. However, how these interact with more central, semantic properties is still debated: While most traditional models assume that semantics comes into play only at late processing stages (Libben, 1998), recent approaches

suggest that compound semantics modulate lexical access already during very early stages of word processing (Marelli & Luzzatti, 2012).

A further interesting issue regarding the processing of compounds is how their production could be described in terms of the “lemma” model (Levelt, Roelofs, & Meyer, 1999). The lemma is an intermediate level between semantic and phonological information linking a word’s semantic and grammatical features. The subsequent level, the lexeme, stores the phonologically specified word form. Within this theoretical framework, the information about the compound status of a word must be stored at the lemma level, where grammatical properties of words are specified. This proposal has received support from neuropsychological data from people with aphasia (e.g., Badecker, Miozzo, & Zanuttini, 1995; Biran & Friedmann, 2012; Delazer & Semenza, 1998).

An alternative model, the independent network model (Caramazza, 1997) also assumes that grammatical and word-form information are stored in separate networks. However, while in this model word-form information is stored in a phonological output lexicon, grammatical features are represented in an independent syntactic network that is linked to word forms but, unlike the lemma-based proposal, it is not an intermediate level between semantics and phonological word forms.

The two models differ in their assumptions about the word-form representations of morphologically complex words—that is, whether they are represented as wholes or in terms of constituent morphemes. In Levelt’s model, morpheme-based representations are assumed at the word-form level (“the single-lemma-multiple morpheme case”, Levelt et al., 1999, but see Marelli, Aggujaro, Molteni, & Luzzatti, 2012, for an alternative view). In contrast, the model proposed by Caramazza and colleagues (Caramazza, 1997; Janssen, Bi, & Caramazza, 2008), while not explicitly dealing with the representation of morphologically complex words, assumes whole word representations for compound words. This conclusion was based on the observation of full-form frequency effects and no morpheme-based

frequency effects in the production of nominal compounds.

COMPOUNDS IN NEUROSCIENCE

In consideration of these facts, it is not a trivial question to ask how compound processing is implemented at neural level—that is, how and where the brain processes compound words. Surprisingly, however, only in the past two decades have systematic investigations of compounding processes appeared in neuroscience.

Compound processing has been the focus of several studies examining the neural instantiation of complex word recognition using electrophysiological techniques (electroencephalography, EEG; magnetoencephalography, MEG). As Fiorentino, Naito-Billen, Bost, and Fund-Rednick (2014) argue in this issue, these techniques make it possible to track the processing of complex words prior to overt behavioural responses, providing new insights into debates regarding the role of morphemes in complex word recognition and contributing to the identification of brain mechanisms linked to the decomposition and combination of morphemes. Thus, electrophysiological research in compounding carries the potential to increase our understanding of how linguistic representations and combinatory operations are instantiated in the brain. A good proportion of these studies address issues regarding the extent to which complex word recognition involves morphological decomposition and composition, and what neurophysiological mechanisms subserve these computations. On the whole, indications in favour of decomposition seem to prevail. The influence of factors like headedness has also been investigated.

While electrophysiological studies mainly consider the comprehension side, the great majority of neuropsychological studies consider production mechanisms. Most of these investigations, using tasks like picture naming, word repetition, reading, and, less frequently, writing, were carried out on people with aphasia (Semenza & Mondini, 2010); further studies were conducted on Alzheimer's disease (Chiarelli, Menichelli, &

Semenza, 2007) and the neglect syndrome (Marelli, Aggujaro, Molteni, & Luzzatti, 2013; Semenza et al., 2011). These studies showed that persons with aphasia may sometimes have a problem in activating the phonological form (lexeme) while they seem to maintain information at the lemma level. Despite difficulties in producing word forms, they may, nonetheless, retain information about the compound's structure, including the grammatical class of each component and the word formation rules needed to correctly bind them (Semenza, Luzzatti, & Carabelli, 1997). Most neuropsychological studies have found clear evidence for decomposition (see, for a review, Semenza & Mondini, 2010). Further important findings concern the role of headedness, which has been found to have a clear influence on processing. Studies in languages like Italian or French, which have both right- and left-headed compounds, have allowed researchers to disentangle the effect of headedness from the effect of position (El Yagoubi et al., 2008; Jarema, Perlak & Semenza, 2010; Marelli & Luzzatti, 2012; Marelli et al., 2013; Semenza & Mondini, 2010).

Different approaches have thus been taken, and different techniques have been used, though with little if any cross-fertilization among the different domains and approaches. Findings in neuroscience did not have significant impact in (psycho)linguistics and vice versa. For instance, Libben and Jarema's (2006) book on compounds extensively reported clinical data collected in language disorders, but the more recent *Oxford Handbook of Compounding* (Lieber & Stekauer, 2009) has a chapter devoted to data from psycholinguistics but hardly mentions data from neurosciences. While generic claims are found about the biological basis of language, there is little reference to clinical and neurophysiological work.

PAPERS IN THIS ISSUE

This special issue collects studies of compound processing from clinical participants as well as studies using neurophysiological techniques and begins with an introductory paper that portrays a novel

psycholinguistic perspective directly supported by available neuropsychological observations.

The first study, by Gary Libben (2014), claims that as a result of acts of lexical processing, the constituents of compound words develop into new lexical representations. These representations are bound to specific morphological roles and positions (e.g., head, modifier) within a compound word. The development of these positionally bound compound constituents creates a rich network of lexical knowledge that facilitates compound processing and also creates some of the well-documented patterns in the psycholinguistic and neurolinguistic study of compounding. Thus, for example, the ways in which even partial activation of a compound constituent can activate families of compounds may be a driving force in the “compound effect” observed by many researchers. The reason for this is that activation of a compound constituent associated to a certain morphological role and position (e.g., *neuro-* in neurosciences, neuropsychology, neuroeconomics, etc.) constitutes a cue to compound structure. This is comparable to the manner in which the activation of the *-ed* marker of past tense in English constitutes evidence that the element to which it attaches must be a verb. The proposal of dedicated positionally bound constituents can also explain why compound constituents are reversed less often in aphasia than might be expected.

The contribution by Marelli, Zonca, Contardi, and Luzzatti (2014) is a group study of picture naming in aphasia. The objective of this study was to assess how lexical processing in aphasia is influenced by the head-modifier structure of nominal compounds. A significant interaction between headedness and constituent position was found: The modifier emerged as being more difficult to retrieve than the head, but only for head-final compounds. This effect emerged for the first time in a group study in aphasia, whereas, previously, only selected case studies had documented a head effect. The results are also consistent with previous data from priming experiments on healthy subjects and provide convincing evidence that compound headedness not only is a theoretical concept but is represented in the cognitive system.

Lorenz and Zwitserlood (2014) investigated spoken naming of compounds and simple nouns as well as determiner retrieval in three participants with aphasia. Determiner-compound noun processing was assessed in receptive and productive tasks, including lexicalized compounds, simple nouns, and novel compounds. The results support the assumption of morphologically structured representations at (output) word-form level, whereas full listing accounts are not supported. The issue of the representation of compounds at the lemma level was also addressed: The data are best compatible with single lemma representations, while no evidence was obtained for decomposed lemma representations.

The paper by Bormann, Romani, Olson, and Wallesch (2014) reports a study of agraphia. The participant produced an unusual high rate of neologistic compounds involving legal or illegal combinations of morphemes. According to the authors, the disruption of selection mechanisms caused excessive build-up of activation and an inability to suppress target competitors. The production of neologistic compounds is compatible with decomposition accounts of the mental lexicon that assume independent representations of modality-specific word forms and modality-specific information about morphological structure.

Friedmann and Gvion (2014) studied the processing of compound nouns in two Hebrew-speaking men with left unilateral neglect, who suffered left text-level neglect dyslexia. Hebrew is read from right to left, and compounds are two word phrases that have a head-first structure. In several compounds the first word is marked morphophonologically, and often also orthographically, as the head of the compound (i.e., signalling that a modifier is following). This study found that when the first word (on the right) included an orthographic cue indicating that it was a head of a compound and hence that a second word was following, fewer words on the left were omitted than when no such cue was present. This was not a general effect of compounds, as this improved reading of the left word only applied to compounds in which the first word was marked orthographically as a head. In other words, reading performance in

text-based neglect dyslexia is modulated by morphosyntax.

Fiorentino et al.'s (2014) study presents electrophysiological evidence for constituent activation in known and novel visually presented compounds and for postdecompositional processes involving these constituents prior to and dissociable from the eventual overt lexical decision response. These findings support models positing across-the-board decomposition of complex words into morphological constituents, counter to models proposing that putatively complex words are primarily or solely processed as undecomposed representations. The results, thus, motivate further electrophysiological research toward a more precise characterization of the nature and neurophysiological instantiation of complex word recognition.

Dirk Koester's (2014) study investigated the neurophysiological correlates of lexical prosody in the comprehension of compound words, examining whether lexical prosody influences the decomposition of spoken compound words. Regarding prosody, (initial) compound constituents differ from the same nouns that are produced in isolation in mean duration, mean fundamental frequency, and the contour of the fundamental frequency. The experiment was based on a number agreement judgement task. The results suggested that lexical prosody influences comprehension such that compound prosody seems to delay and to make the specification of number information more difficult for initial compound constituents. Thus, when judging number agreement, compound prosody leads to a delayed neurophysiological processing of number information and makes judgements more difficult than for nouns with a single noun prosody. These findings are in line with predictions from dual-route models that assume a flexible configuration of the processing routes. It is suggested that prosodic information is used to coordinate the parsing routes.

The paper by Arcara, Marelli, Buodo, and Mondini (2014) is an event-related potential (ERP) study addressing the hypothesis that Italian compounds are processed differently according to their head position. Head-initial non-noun compounds, head-final noun-noun compounds,

and exocentric verb-noun nominal compounds were shown to normal participants in the context of a lexical decision task. Results indicate that head-initial and head-final noun-noun compounds are stored differently—that is, the linear order of head and modifier influences their processing. In particular, the data suggest that head-initial noun-noun compounds are processed as syntactic-like structures rather than morphological complex words.

The study by Arcara, Semenza, and Bambini (2014) investigated the processing of compound as compared to other noncompound complex words in a reading task with eye movement recording. Both head-initial and head-final compounds were included, in order to test whether the position of the head can influence the reading process. After ruling out the effects of length and frequency, they observed that pseudocompounds with a segment homograph to a real word in the initial part (e.g., “*cocodrillo*”, “*crocodile*”, where “*cocca*”, coconut, is a real word neither morphologically nor semantically related to the whole word, and “*drillo*” is neither a word nor a suffix) elicited longer total reading times than all other types of complex words, including compounds. These results suggest that a word structure resembling a compound may induce longer processing, possibly in relation to unexpected morphological structures. Furthermore, the effect of headedness was qualified by several interactions involving constituent and compound frequency as well as length.

CONCLUSIONS

On the whole this special issue collects a variety of examples of how work on compounds can be conducted in the domain of cognitive neuroscience. Several different techniques have been used, obtaining interesting results. In particular some important issues have been deeply investigated, with converging results. Evidence for decomposition, mostly compatible with dual-route theories, has been reported, and the processing of the head has been shown to be independent of that of the modifier. These findings are compatible with previous

literature but constitute significant progress providing a solid basis from which to launch new research questions. For example, while the grammatical class of the components has been previously investigated, the type of relations between the components (e.g., subordinate, coordinate, attributive, see Bisetto & Scalise, 2005) has received much less attention, and the contrast between endocentric and exocentric compounds has not been addressed. As Libben (2014) suggests, models of the neural instantiation of morphological knowledge in the brain may better capture the dynamic, flexible, and adaptive nature of morphological ability. In order to follow this and other suggestions, precise theories are needed, specified in terms of a potentially testable cognitive architecture. To this end, a joint effort is needed that includes linguists, psycholinguists, and neuroscientists. This special issue is just a start. Cross-fertilization among different disciplines is crucial, otherwise, the question of how our minds combine one word with another word to obtain yet a different word, a fundamental linguistic ability, would remain only partially and unsatisfactorily answered.

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