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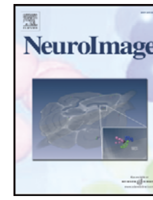

Morphological priming in overt language production: Electrophysiological evidence from Dutch

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ABSTRACT

The present study investigated morphological priming in Dutch and its time course in overt speech production using a long-lag priming paradigm. Prime words were compounds that were morphologically related to a picture name (e.g. the word *jaszak*, 'coat pocket' was used for a picture of a coat; Dutch *jas*) or form-related monomorphemic words (e.g. *jasmijn*, 'jasmine'). The morphologically related compounds could be semantically transparent (e.g. *eksternest*, 'magpie nest') or opaque (e.g. *eksteroog*, lit. 'magpie eye', 'corn', for a picture of a magpie, Dutch *ekster*). Behavioral and event-related potential (ERP) data were collected in two sessions. The production of morphologically related and complex words facilitated subsequent picture naming and elicited a reduced N400 compared with unrelated prime words. The effects did not differ for transparent and opaque relations. Mere form overlap between a prime word and a target picture name did not affect picture naming. These results extend previous findings from German to another language and demonstrate the feasibility of measuring cognitive ERP components during overt speech. Furthermore, the results suggest that morphological priming in language production cannot be reduced to semantic and phonological processing. The time course of these priming effects as reflected in the ERP measure is in accordance with a meta-analytic temporal estimate of morphological encoding in speaking [Indefrey, P., & Levelt, W.J.M. (2004). The spatial and temporal signatures of word production components. Cognition, 92, 101–144.] suggesting that morphological relations are encoded at the word form level.

Introduction

Human communication requires numerous, distinct expressions to convey our thoughts. Our vocabulary, i.e. the mental lexicon, is supposed to contain these expressions and it is at least in principle infinite. We can create new words – if necessary – because words are – to a large extent – arbitrary sound-meaning mappings, but it is also possible to combine existing words and even parts of words in meaningful ways to form new linguistic expressions. Theories of morphology describe the formation of words, i.e. their internal structure. However, up to date, there is no agreement on the brain's signature of morphological processing. In particular, little is known about the electrophysiological correlates of morphological processes, especially in language production. In the present study, we investigated morphological effects in overt language production and its time course using behavioral (i.e. reaction times) and electrophysiological measures of these lexical processes.

In contrast to language production, morphological priming has received much attention in language comprehension. Without attempting to review this literature exhaustively, some behavioral effects led to the suggestion that morphological decomposition is a rather late process relative to lexical identification, i.e. morphological information becomes available after whole-word representations have been activated (Greber and Frauenfelder, 1999; Giraudo and Grainger, 2000, 2001; Zwitserlood, 2004). Other behavioral studies and the use of event-related potentials (ERPs) have questioned this theoretical view (e.g. Longtin et al., 2003; Rastle et al., 2004; Barber et al., 2002; Domínguez et al., 2004; Lavric et al., 2007).

These latter studies provide evidence for an early morphological decomposition process during visual word recognition (cf. Taft and Forster, 1975). For example, Lavric et al. (2007) reported comparable priming effects for pairs of words that were morphologically related (e.g. cleaner – clean) and pairs that only superficially had a morphological relation (e.g. corner – corn). The effects for word pairs with a mere form relation (e.g. brothel – broth; -EL is not an English suffix) were not comparable to the effects of (real or superficial) morphological relations. This result led to the conclusion that written words are morphologically decomposed irrespective of their real morphological structure. Interestingly, the morphological

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overlap affected the N400 component in the ERP related to ease of lexical–semantic integration of the words (see also Barber et al., 2002; Domínguez et al., 2004; but Morris et al., 2007 for graded effects of semantics). Recent investigations of the functional neuro-anatomical correlates of morphological decomposition in visual word recognition also reported evidence consistent with morphological decomposition during early stages of visual word processing (Devlin et al., 2004; Gold and Rastle, 2007).

The present study is not concerned with comprehension, but with language production. Language production is generally characterized by a sequence of cognitive processes involving different types of information. The four major stages are conceptual preparation, lexical access, phonological processing, and articulation (Caramazza, 1997; Dell, 1986; Garrett, 1988; Levelt, 1989; Levelt et al., 1999). During speaking – for example when naming a picture – the conceptual representation of the intended object is activated. This activation spreads to lexical representations of these concepts. From there, phonological information is retrieved (word form encoding) that is finally used for articulation by invoking the corresponding gestural scores. However, details of this architecture, e.g. whether the activation flow is cascading or involving discrete stages is still debated (Damian and Bowers, 2003; Morsella and Miozzo, 2002; Navarrete and Costa, 2005; Jescheniak et al., 2002 vs. Levelt, 2001; Roelofs, 2003).

Different morphological mechanisms have been investigated in language production. Most behavioral research focused on the processing of inflections (Schriefers et al., 1992), verb-particle constructions (Schriefers et al., 1991; Roelofs, 1998), gender marking using free vs. bound morphemes (Lemhöfer et al., 2006; Schiller and Costa, 2006), and derivations (Schriefers et al., 1992; Zwitserlood et al., 2000). The current study aims to contribute to the research on compound word production.

Compounds are combinations of free morphemes (here called constituents) whereby most compounds are internally structured. One constituent has a distinguished status in that it determines the compound's syntactic category and usually its semantic class (the so-called *head*; Selkirk, 1982; Di Sciullo and Williams, 1987). Compounding is in principle a recursive mechanism, i.e. compounded words can be used to create another compound. For example, *birthday* (Birth + Day) can be concatenated with Cake to form *birthday cake*. Semantically transparent compounds such as *birthday cake* are usually distinguished from semantically opaque compounds which are not related to the meaning of their constituents (e.g. *wild-goose chase*; Sandra, 1990; Zwitserlood, 1994). Languages also differ with respect to whether their compounds are left- or right-headed. Dutch, the language under investigation, as well as English and German, is right-headed regarding compound words (Booij, 2002; Fabb, 2001).

The production of words is assumed to be prepared serially. Especially morphologically complex words have been suggested to be prepared incrementally from left to right (Roelofs, 1996; Roelofs and Baayen, 2002). For instance, Roelofs (1996) compared the production latencies of sets of words that were homogeneous regarding their initial syllable (e.g. *bijbel*, *bijna*, *bijster*; 'bible', 'almost', 'loss') with sets of words that were heterogeneous (e.g. *bijbel*, *hersens*, *nader*; 'bible', 'brain', 'further'; the so-called preparation paradigm). The phonological overlap resulted in a facilitation of 30 ms in homogenous sets. However, if the initial syllables also constituted morphemes (e.g. Bij in *bijvak*, *bijrol*, *bijnier*; 'subsidiary subject', 'supporting role', 'kidney'), the facilitation was significantly larger; homogeneous sets were now produced 74 ms faster than heterogeneous ones. In contrast, non-initial morphemes in homogeneous sets (e.g. Boom in *stamboom*, *spoorboom*, *hefboom*; 'pedigree', 'barrier', 'lever') did not lead to a significant preparation effect. Roelofs (1996) concluded that morphemes are a planning unit in the production process and that language production proceeds incrementally from left to right.

The separate access of morphemes is suggestive of decomposed preparation of compound words (Levelt et al., 1999; Caramazza et al., 1988; Taft and Forster, 1976). That is, compounds do not have to be stored and accessed as whole units. This conception is in accordance with linear frequency effects of the constituents but not of the whole compound; higher constituent frequency is associated with shorter naming latencies (Bien et al., 2005).

The error analysis of aphasic patients' compound production also supports the decompositional view. Misproductions were found to be morpheme-based, i.e. errors such as constituent substitutions decreased with decreasing transparency and increasing frequency of the constituents (Blanken, 2000; see also Badecker, 2001; Hittmair-Delazer et al., 1994; but Bi et al., 2007).

Most of these investigations on compound production used behavioral measures. In contrast, relatively little is known about the neurocognitive correlates of compound production. Neurocognitive measures such as the electroencephalogram (EEG, as the basis for event-related potentials, ERPs) and the magnetoencephalogram (MEG) have proven useful in testing (and confirming) decompositional processes of compound comprehension in the visual and auditory modality (Fiorentino and Poeppel, 2007; Koester et al., 2007; see also Koester et al., 2004; Krott et al., 2006). Of particular interest here is an ERP study that investigated effects of morphological decomposition in word reading by McKinnon et al. (2003). These authors compared the ERPs in response to words consisting of bound morphemes (e.g. Re-Ceive), non-words containing no real morphemes (e.g. *Flermuf), and, critically, non-words consisting of bound morphemes (e.g. *In-Ceive). As expected, a reduced N400 amplitude was observed for words compared to unconcatenated non-words (e.g. **flermuf*). This reduction was interpreted as a standard effect of lexical status. Importantly, concatenated morphemes that result in non-words (e.g. **inceive*) elicited also a reduced N400 amplitude that was comparable to the one elicited by words. McKinnon et al. (2003) concluded that the N400 is not only sensitive to lexical status per se but also to morphological decomposition.

In contrast to reaction times (RTs), ERPs with their high temporal resolution can trace cognitive processes more directly before or even without an overt response (Kutas and Van Petten, 1994). Therefore, ERPs are particularly valuable for investigating the time course of cognitive processes. The limited use of electrophysiological measures in language production may result in part from two methodological issues. Firstly, overt speech can result in movement artifacts. Secondly, the interpretation of particular effects in the widely used picture-word interference paradigm is sometimes ambiguous as to whether the effects are associated with processes of production or comprehension, i.e. processing the distractor word.

These issues have been addressed differently. To avoid movement artifacts, the overt response can be delayed in ERP studies (e.g. Jescheniak et al., 2002). Strictly speaking, such a procedure restricts the interpretation to preparation processes which might not be identical to overt speech production. Alternatively, one may use a different experimental task to avoid an overt vocal response, e.g. phoneme detection or go/no-go tasks (e.g. Jansma and Schiller, 2004; Schiller, 2006; Schmitt et al., 2000, 2001). An interesting solution to the second issue emerges from work by Zwitserlood et al. (2000), especially with regard to morphology.

Zwitserlood et al. (2000) investigated morphological effects in language production by comparing the standard, immediate picture-word interference paradigm with a delayed variant. In the delayed variant, the prime word (termed "distractor" in the standard picture-word interference paradigm) preceded the target picture by 7–10 trials. Prime words were read aloud and pictures were named overtly. That is, in any trial only one stimulus is presented to the participant and, consequently, effects during picture naming are not conflated with the reading of prime words. Hence, the delayed variant of the picture-word interference paradigm can be combined profitably with