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Event-related potentials indicate context effect in reading ambiguous words

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ABSTRACT

The aim of the study was a comparison of lexical and contextual factors in understanding ambiguous words in German. First, a sample of native speakers selected 56 words having maximally strong differences between a dominant and a subordinate meaning. After this, another sample from the same population was visually presented with sentences that activated dominant or subordinate meanings of the words and were accompanied by probes associated with dominant or subordinate meanings. This resulted in a crossed design with two factors: sentence dominant vs. sentence subordinate and probe dominant vs. probe subordinate. An analysis of event-related brain potentials revealed a large, long-lasting and highly-significant N400 wave whenever the meaning of the probe was incongruent with the meaning of the sentence and the lack of this wave whenever the two meanings were congruent. In the typical N400 space and time, the effect was independent of whether the lexical word meaning was dominant or subordinate. At other sites and times, however (e.g., at lateral frontal electrodes F7/F8, and after 700 ms), the congruence effect was significant after dominant sentences only. The data indicate that lexical factors have a rather limited influence on the activation of a particular meaning of ambiguous words. A strong context can virtually override even a very strong difference in the preference for different meanings.

1. Introduction

A large portion of content words in most languages have several meanings. *Jam* (jelly and blocking), *bank* (riverside and financial institute) or *salmon* (animal and meal) are only few examples of thousands. Each confrontation with such words creates some ambiguity. How do we recognize which meaning is meant at a given moment? What meaning is activated, and if all of them, in which order? Is the strength of meaning activation determined by lexical factors (e.g., frequency of use) or by the immediate context (of the sentence and, broader, of the whole conversation)? And if both lexical and contextual factors play a role, what is their exact relationship?

This issue is debated by linguists for decades (e.g., Glucksberg, Kreuz, & Rho, 1986; Lucas, 1987; Swinney, 1979). A comprehensive review of the numerous studies cannot be done within this brief introduction, but most generally, three extreme views can be distinguished, each of which is partially supported by psycholinguistic data. Perhaps the oldest (but not outdated) are models which claim that initially all meanings of an ambiguous term are activated independently of context (e.g., Swinney, 1979). Only at a later stage they are compared with the context and inappropriate meanings are inhibited. Other models maintain, however, that there is a considerable asymmetry between a word's dominant and subordinate meanings. While the former is activated in any context, the latter requires a strong contextual bias for activation (e.g., Tabossi, 1988). On the other hand, some data indicate that a strong context completely determines the processing; according to this view, context-inappropriate meanings are not activated at all regardless of how strong they may appear when evaluated without context (Glucksberg et al., 1986; Simpson, 1981).

More recently, Giora (1997) developed a graded salience theory that became very influential in the domain of metaphor processing. According to this model, several important lexical features of metaphoric expressions are integrated in their salience. The way of how an expression is processed differs much more between its salient and non-salient meanings than between metaphoric and literal meanings, or than between figurative and non-figurative metaphors. Metaphors are ambiguous words, too, simply because they can also be used in a literal sense (compare, e.g., *This boy is*

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a pig and *This animal is a pig*), and Giora's model implies, in fact, that the graded salience approach can be applied to other cases of ambiguity (Giora, 2002, 2007). The dominant meaning, being highly salient, is activated early, automatically and independently of context. On the second stage of analysis, this preferred meaning is compared with the context and, as soon as a contradiction is detected, further (less and less salient) meanings get activated.

The technique of event-related brain potentials (ERP) is appropriate to analyze this issue. Particularly, the N400 component (Kutas & Hillyard, 1980) can be used as a measure of semantic activation. In a typical N400 experiment, ambiguous words are presented in a context supporting either their dominant or subordinate meaning. Briefly after an ambiguous word, a probe word is delivered. This probe is semantically related to one of the meanings of the ambiguous word (Table 1). This results in a crossed design with the dominant versus subordinate context and a dominant versus subordinate probe. Additional factors might be the strength of the context, the nature of ambiguity (e.g., metaphor, metonymy), etc.

According to the two-stage model described above the dominant meaning is activated first regardless of the context. Therefore, a probe associated with this meaning should, if presented "early enough", elicit a smaller N400 than a probe associated with any other meaning of the same word. Because in the next phase, according to the same model, the word is compared with the context, at some later time moment the N400 amplitude should be smaller to context-related (congruent) than to context-unrelated (incongruent) probe. In other words, the N400 amplitude should depend on the salience in an earlier time interval but on the context-congruence in a later time interval. For example, after a sentence *The chess player moved his queen* the probe *majesty* should elicit a smaller N400 than the probe *board* at an earlier time point, but the opposite should be observed at the later time point. This theoretical model does not exactly define the terms "earlier" and "later". However, this can be specified in experiments.

To our best knowledge, the first investigation of this kind was carried out by Van Petten and Kutas (1987, 1990) who presented ambiguous words in the contexts that supported their subordinate meaning (e.g., *The judge entered the room, and the people rose*). The sentences were followed by probes related either to the same meaning (congruent, e.g., *stand*) or to the dominant meaning (incongruent, e.g., *flower*), or completely unrelated (e.g., *moon*). When the stimulus onset asynchrony (SOA) between the ambiguous word and the probe was long (700 ms), incongruent probes elicited the same N400 as irrelevant words, while the N400 to congruent probes was substantially reduced, indicating that the subordinate meaning was activated but the dominant was not. When the SOA was short (216 ms), the N400 to congruent probes remained small, and the N400 to incongruent probes slightly decreased (as compared with irrelevant probes) after 500 ms poststimulus. As can easily be seen, this temporal order is not in line with the prediction of the two-stage model. On the basis of that model *flower* is expected to elicit a small initial N400, which would later increase, but exactly the opposite was observed in the experiment. The authors interpreted their finding as evidence that the context determines from the very beginning which meaning of the ambiguous word is activated. The brief N400 suppression in the short SOA condition after 500 ms was explained as a result of the backward activation of the dominant meaning by means of the dominant-related probe (Van Petten, 1995).

The partial disadvantage of this study was the lack of symmetrical conditions in which the context would support the dominant, rather than subordinate, word meaning. This was done by Swaab, Brown, and Hagoort (2003) who used the complete experimental design like that presented in Table 1 with short versus long (100 and 1250 ms, respectively) SOA. The effect of congruence was very strong with both SOAs, confirming that the context strongly contributed to the activation of a particular word meaning (Swaab et al., 2003). Nevertheless, the N400 to incongruent probes, though rather large, was significantly smaller than that to unrelated words. This indicated that both meanings were active, and that the context only increased activation of one meaning without suppressing the other one. At the long SOA, moreover, a weaker but significant effect of dominance was also found, i.e., N400 amplitudes to both congruent and incongruent probes were larger when the probes were related to the subordinate, rather than dominant, meaning (Swaab et al., 2003).

Although this can be interpreted as a proof that both factors dominance and context are operating, the data are still discordant with the two-stage model. It remains unclear why the inappropriate dominant meaning was relatively deactivated already 100 ms after word presentation, but again reactivated 1150 ms later. Notably, no such late activation was found in elderly subjects (Swaab, Brown, & Hagoort, 1998). All N400 effects found in these studies covered the whole N400 time window, thus giving no support to Van Petten's (1995) hypothesis of backward activation. The long SOA at which the effect of dominance was found is also hardly compatible with this hypothesis.

Other electrophysiological studies employed single words, rather than sentences, as a context for ambiguous words (Atchley & Kwasny, 2003; Chwilla & Kolk, 2003; Klepousniotou, Pike, Steinhauer, & Gracco, 2012; Lee & Federmeier, 2006; Meyer & Federmeier, 2007; Pylkkänen, Llinás, & Murphy, 2006; Titone & Salisbury, 2004). This procedure (e.g., *dance – ball* versus *sphere – ball*) results probably in a weaker bias toward the primed meaning than a sentence context like *The children play with a ball*. Chwilla and Kolk (2003) showed, for example, that two related words enhance each other's effect. Nevertheless, one-word and two-word context exerted rather strong effects manifested in a decreased N400 both to the primed meaning of the ambiguous word (Chwilla & Kolk, 2003; Klepousniotou et al., 2012) and to the congruent probes (Meyer & Federmeier, 2007; Titone & Salisbury, 2004). However, in those studies which made a distinction between dominant and subordinate meanings the asymmetry

Table 1
A typical scheme of an experiment designed to compare context and lexical strength, with examples from the present study. First, a sentence is presented that ends with an ambiguous word (in the present case, *caterpillar*) and biases it toward either its dominant meaning (*a machine*), or subordinate meaning (*an insect*). Briefly after this end word an additional probe word is presented, which is not a part of the sentence but is semantically related to one of the meanings. The combination of the dominant versus subordinate word meaning in the sentence, and the dominant versus subordinate probe meaning, results in four conditions which will be referred to as Dom/Dom, Dom/Sub, Sub/Dom and Sub/Sub. Two of the conditions (Dom/Dom and Sub/Sub) are semantically congruent, and the other two (Dom/Sub and Sub/Dom) are semantically incongruent. In other experiments the context can be built using single words rather than sentences (e.g., *fruit – jam* versus *car – jam*). Further, a third kind of probe is possible, fully unrelated to either meaning of the last word (e.g., *moon*).

Sentence	Probe	Context meaning	Probe meaning	Condition name
In this construction, workers used a lorry and a caterpillar	*machine*	dominant	dominant	Dom/Dom
In this construction, workers used a lorry and a caterpillar	*insect*	dominant	subordinate	Dom/Sub
This beautiful butterfly develops from an ugly caterpillar	*machine*	subordinate	dominant	Sub/Dom
This beautiful butterfly develops from an ugly caterpillar	*insect*	subordinate	subordinate	Sub/Sub