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Electrophysiological evidence for relation information activation in Chinese compound word comprehension

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ABSTRACT

How constituent concepts of a compound concept are put together for meaning construction is an important question in cognition. Using English noun–noun compounds with a modifier+noun structure, researchers have observed relation priming between compounds that share the same relation (*snowball* vs. *snowman*) compared with those that do not (*snowball* vs. *snowshovel*), suggesting explicit use of relation information during comprehension of compound expressions. The present study examined the temporal characteristics of relation priming with event-related potentials. Participants were presented with lists of two-character noun+noun Chinese compound words and judged whether each was semantically meaningful or not. About 260 ms following word presentation, the semantic N400 response was significantly reduced if a word was preceded by a prime with the same first character, indicating semantic processing of constituent morphemes. However, N400 was not modulated by manipulation of relation priming until around 340 ms. Results confirm the use of relation information in semantic composition, but more critically provide the first piece of evidence that compound word comprehension involves serial processing where constituent morphemes are activated in stage one and bound by their relation in stage two.

1. Introduction

Concepts are the basic units of thinking and other higher cognitive processes. Combining existing concepts to create new concepts offers an effective way to express new meanings. For example, “computer” and “desk” can be combined to construct the new expression “computer desk”. Noun–noun combination is probably the most numerous type of concept combination, among which the modifier+head noun subtype has been extensively studied (Murphy, 1990; Zhou, 2007).

Albeit the concise form in which two nouns are put together to form a new concept, the resultant meaning involves not only the sum of meanings of the two constituent concepts but also the semantic relation between them. For example, “dog scarf” can be interpreted as “a scarf for a dog to wear” using the relation “for” or as “a scarf with a dog's image” using the relation “with” Raffray, Pickering, and Branigan (2007). Some linguists tried to analyze all relations that can be used in forming compound concepts. For example, Levi (1978) classified relations into 12 classes, such as “noun FOR modifier”, “noun HAS modifier” etc. Others proposed that the number of relations is indefinite (e.g., Kay & Zimmer, 1976). Following this tradition, the more recent CARIN theory assumes that compound concepts are formed by binding two constituents with a specific thematic relation (Gagné & Shoben, 1997). According to this theory, relations are not only the basis of compound concepts construction, but also important in their interpretation. Specifically, interpretation is a process where the appropriate relation is selected to depict the way the modifier and the head are connected.

Gagné (2000) showed that novel modifier+noun combinations can be primed by combinations sharing the same modifier and the same relation. For example, responses to a compound (e.g., student vote, vote *by* a student) were faster when the compound was preceded by a compound using the same relational structure (e.g., student accusation, accusation *by* a student) than when preceded by a compound using a different relational structure (e.g., student car, car *of* a student).This finding, referred to as relation priming, indicates that the relation structure plays a role in compound concept interpretation. Further, Gagné and Spalding (2004) found that relation priming also exists when interpreting

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familiar noun+noun compound words, i.e., "snowman" (man *made of* snow) would prime "snowball" (ball *made of* snow) more than it primes "snowshovel" (shovel *for* removing snow). This suggests that even for compound words that are familiar and lexicalized, their meaning is probably not retrieved directly as a whole. Rather, there seems to exist a process of semantic composition where the whole word's meaning is construed using the relation information to connect the meanings of the two constituents.

As Gagné and Spalding (2009) pointed out, evidence for semantic composition is still scant and needs to be strengthened. Relation priming should be further studied as it provides a paradigm to demonstrate the integration process and to reveal the specific mechanisms of integration. When understanding a compound word, if one need not only combine semantic activation of its constituents, but also incorporate them in a relational structure, an immediate question follows, that is, what is the order of morpheme activation and relation activation? Is it that as constitute meanings are retrieved, relation information is activated and used at the same time, or that relation information begins to take effect only after constitute meaning retrieval has completed?

Clearly, this question goes beyond demonstrating the use of relation information but is concerned with how that information is used, and shall help to constrain the theorization of relation priming. However, extant research has not yet addressed this question explicitly. As an exception, Gagné, Spalding, Figueredo, and Mullaly (2009) found that the occurrence of relation priming required not only the prime and target words sharing one constituent and the relation but also the shared constituent playing the same morphosyntactic role (i.e., modifier or head). This led them to infer that morphemes were activated and assigned specific morphosyntactic roles before the relation information was activated. Apparently, to learn about the order of morpheme activation and relation activation, one way would be to use ERP measures with high temporal resolution to identify the time course for relation activation and compare it with that for the constituent morphemes. The present study was intended to do so with Chinese compound word stimuli.

Relation priming has been demonstrated in English, French and Indonesia (Ji & Gagné, 2007; Storms & Wisniewski, 2005). Unlike alphabetic scripts, Chinese word construction stresses compounding by which most Chinese vocabulary was formed. There has been one study by Ji and Gagné (2007) that already demonstrated relation priming for Chinese modifier+head noun compounds. The first goal of the present study was to replicate their study. We would present participants with lists of two-character words and asking them to judge whether each word was semantically meaningful or not. Depending on the relationship between the two words in the prime trial n–1 and the target trial n, there were three experimental conditions. (1) Same relation: the two words used the same modifier and the same relation (*snowball–snowman*); (2) Different relation: the two words used the same modifier but different relations (*snowshovel–snowman*); (3) Neutral: the two words differed in both morphemes and the relation (*eggshell–snowman*).

One difference from Ji and Gagné (2007) was that our study was limited to modifier repetition while they examined both modifier repetition and head repetition. Another difference was that we matched the semantic relatedness between the prime and target across the Same and Different conditions, as well as the likelihood that the head noun in the prime and the target belong to the same semantic category. These two factors can potentially confound interpretation of the relation priming effect.

As in their study, we expected better performance for the Same and Different conditions compared with the Neutral one, as a result of repetition priming. We also expected better performance for the Same condition than the Different condition, which would indicate the presence of relation priming.

More importantly, we would record EEGs to compare the electrophysiological responses to the target when preceded by different types of prime. For the ERP measures, we would focus on two components, the centro-parietal N200 and the semantic N400.

As a recent discovery (Zhang et al. 2012), the N200 response is a widespread negative deflection elicited by two-character Chinese words about 200 ms post-stimulus onset with a centro-parietal focus in scalp distribution. There is evidence that it is a neural marker associated with orthographic processing in Chinese as opposed to semantic or phonologic processing. This response seems to be specific to Chinese as no similar effects had been reported in word recognition studies involving alphabetic scripts under similar experimental conditions. We have proposed a meaning-spelling theory for written Chinese at the vocabulary level to explain the N200 response based on the Chinese script's emphasis on visual processing (Zhang, 2011). One puzzling feature of the N200 response is that its amplitude is significantly enhanced upon immediate word repetition. Such repetition enhancement also occurs even when only part of a word is repeated (Exp. 6 in Zhang et al., 2012).

As we used 2-character words here, we expected to see N200 responses that would differ across the Neutral condition and the other two conditions (Same and Different conditions). Specifically, enhanced N200 amplitude should be obtained for both the Same and Different conditions compared with the Neutral condition, due to the partial orthographic repetition in the first two conditions. No difference would be expected between the latter two conditions as they differed from each other in semantic properties but not in orthography.

The widely-studied N400 component peaking in between 300 and 400 ms is known to be associated with semantic processing. As N400 is also sensitive to repetition, we expected N400 reduction for the Same and Different conditions compared with the Neutral condition, due to the shared modifier between the prime and the target. Additional N400 reduction should occur due to the stronger prime-target semantic relatedness in the former two conditions compared with the latter condition, reflecting semantic priming. As the former two and the latter conditions differed in the first morpheme, the time point when N400 starts to differentiate between the two can be taken to signify semantic processing of the morphemes.

The Same and Different conditions were set up in such a way that the behavioral differences between the two conditions could be attributed to relation priming. Consequently, differences in the ERP responses between the two conditions would be attributed to relation activation. That is, the ERP difference between the Same and Different conditions would reveal the neural correlate of relation priming. One possibility is that this difference occurs within the N400 time window. As N400 is known to reflect semantic processing and in particular semantic integration (e.g., Kutas & Van Petten, 1994; Chwilla, Kolk, & Mulder, 2000; Friederici, 1995; Holcomb, 1993; Van Berkum, Brown, & Hagoort, 1999), such a result would indicate that relation information is activated within this time window and used during the semantic integration process when the compound word is interpreted. Alternatively, if the two conditions do not differ in N400, it would indicate that relation information, though activated during task performance, is not involved in the semantic interpretation of the compound word, which would lead to different explanations of the behavioral relation priming effect (e.g., relation information is used after compound comprehension has completed).

Briefly, the time point when the ERP waveform starts to differentiate between the Same and Different conditions should indicate the time when relation information is activated. Comparison of this