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ERP and behavioral effects of semantic ambiguity in a lexical decision task

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In the present study we examined electrophysiological and behavioral correlates of ambiguous word processing. In a lexical decision task, participants were presented with ambiguous words with unrelated meanings (i.e., homonyms; e.g., *bat*), ambiguous words with related meanings (i.e., polysemes; e.g., *newspaper*), and unambiguous words (e.g., *guitar*). Ambiguous words elicited larger N400 amplitudes than unambiguous words and showed an advantage in RTs. Importantly, no differences were found between homonyms and polysemes, on either N400 amplitudes or in RTs. These results suggest that ambiguous words, regardless of the relatedness between their meanings, benefit from enhanced semantic activation in comparison to unambiguous words during word recognition.

1. Introduction

Understanding how meaning is retrieved from printed words and how it is represented in the mind are two primary goals of word recognition research. A fruitful line of research has been devoted to elucidate how orthography and semantics interact during word recognition, and to examine which semantic variables play a role in this process. Among such variables, semantic ambiguity has been one of the most studied. Semantic ambiguity refers to a linguistic phenomenon in which an orthographic form is mapped to more than one meaning (e.g., the word *pupil*, which means both *a student* and *the opening in the iris of the eye*). Given this one-to-many relation between orthography and meaning, semantic ambiguity poses intriguing questions for word recognition research. One central issue is whether ambiguous words have one or multiple lexical/semantic representations. For instance, are both meanings of the word *pupil* (e.g., *student* and *part of the eye*) included in the same lexical/semantic representation, or are they listed in separate lexical/semantic representations? A further crucial question is how orthography and semantics interact during the recognition of ambiguous words. Do the meanings *student* and *part of the eye* compete during the recognition of the word *pupil*? Or rather, does having two meanings, and thus more semantic information, facilitate the recognition of such a word? The aim of the present study was to shed some light on these questions by examining the behavioral and electrophysiological correlates of ambiguous word processing.

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Rubenstein, Garfield, and Millikan's (1970) were the first to address some of these issues. Its main finding was that ambiguous words were recognized faster than unambiguous ones in a lexical decision task (LDT; a task in which participants decide whether a string of letters is a real word or not). Since the pioneering work of Rubenstein et al. (1970), there have been many reports of such a facilitation for ambiguous words in LDT (i.e., the *ambiguity advantage*) (e.g., Borowsky & Masson, 1996; Hino & Lupker, 1996; Hino, Lupker, & Pexman, 2002; Jastrzembski & Stanners, 1975; Jastrzembski, 1981; Kellas, Ferraro, & Simpson, 1988; Millis & Button, 1989; Pexman, Hino, & Lupker, 2004).

The ambiguity advantage appears to be a consistent effect in the literature (see, however, Rodd, Gaskell, & Marslen-Wilson, 2002). For this reason, it has had significant implications for models of word recognition, and has also received different explanations. Some accounts propose that ambiguity effects are located at the surface level of the representation of words (i.e., orthography/phonology), whereas others suggest that they are located at the semantic level of representation (see Armstrong & Plaut, 2016, for an overview). With respect to the former, it is worth mentioning the Parallel Distributed Processing (PDP) model of word recognition proposed by Kawamoto, Farrar, and Kello (1994). This model consists of two processing modules representing the orthography and semantics of words. The model was trained with pairs of activation patterns representing the form and meaning of the words. After the training phase, the authors assessed the performance of the network by presenting just the orthographic pattern of the words, observing that ambiguous words reached the criterion for a lexical decision faster than unambiguous words (i.e., the orthographic units of the model achieved their maximum level of activation faster when they were presented with an ambiguous word). To explain this behavior, the authors showed that the network tried to compensate for the inconsistent orthographic-to-semantic relation for ambiguous words (i.e., one orthographic form associated with multiple meanings) by strengthening the connection weights between their orthographic units. These stronger connection weights between orthographic units would serve to speed up the settling of the orthographic representation of ambiguous words, hence facilitating lexical decisions.

With respect to those accounts that have focused on semantics, it has been suggested that there would be an advantage for ambiguous words during word recognition because they elicit a larger amount of semantic activation (i.e., *semantic-based accounts*; e.g., Borowsky & Masson, 1996; Hino & Lupker, 1996). For instance, based on interactive activation principles, several authors have proposed that after the presentation of an orthographic input, the activation would flow bidirectionally between the orthographic and semantic levels (Balota, Ferraro, & Connor, 1991; McClelland & Rumelhart, 1981). In addition, they assumed that a word would be recognized in a LDT when the activation of its orthographic representation reached a recognition threshold. With these assumptions in place, the explanation of the ambiguity advantage is straightforward: because ambiguous words have more than one semantic representation, they would cause a larger semantics-to-orthography feedback than unambiguous words, and thus would reach the orthographic recognition threshold faster. A similar account was provided by the PDP model of Borowsky and Masson (1996). In this model, words were represented as patterns of activation across orthographic, phonological and semantic processing units. Additionally, a word was thought to be recognized when the level of activation of the network reached a given threshold. The level of activation of the network indicated the distance from the current state of the network to the pattern of orthographic and semantic activation corresponding to a known word; that is, the higher the activation of the network, the lower the distance to a learned pattern. The simulation data showed interesting behavior when ambiguous words were presented to the model, because in those cases the meaning units of the network settled faster into a state in which the two meanings of the ambiguous word were partially activated. Since these blend states were similar to both learned semantic patterns of the word, ambiguous words elicited more semantic activation and reached the criterion for a lexical decision faster than unambiguous words.

It should be noted that according to semantic-based accounts, the ambiguity advantage is closely related to the so-called semantic richness effects reported in word recognition research. Work on semantic richness is devoted to examine to what extent the amount of semantic information of a word influences its recognition (Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Pexman, Siakaluk, & Yap, 2013). Semantic richness effects in behavioral responses are quite homogeneous, in that words having more or richer semantic information (e.g., number of semantic features, number of semantic neighbors, or number of word associates) are associated with faster response latencies in a number of experimental tasks, such as LDT, naming and semantic categorization (Pexman et al., 2008). In addition, semantic richness effects have also been found in EEG studies. Particularly, the amount of semantic information a word contains seems to modulate the N400 component, a negative-going potential that is thought to reflect mainly semantic processing (see Kutas & Federmeier, 2011 for a review). For example, there is evidence, a) that concrete words elicit larger N400 amplitudes than abstract words (Kounios & Holcomb, 1994; West & Holcomb, 2000), b) that words with many semantic features are associated with larger N400 amplitudes than words with few semantic features (Amsel, 2011; Rabovsky, Sommer, & Rahman, 2012), and c) that words with many associates show a larger N400 than words with few associates (Laszlo & Federmeier, 2011; Müller, Duñabeitia, & Carreiras, 2010).

Taking into account the above evidence, it follows that the more or richer semantic information a word has, the more semantic activation it engages, and the larger the N400 it elicits (see, however, Taler, Kousaie, & Lopez Zunini, 2013). In fact, it has been suggested that the N400 component may reflect the amount of semantic activity before the orthographic and semantic levels have settled, thus providing a temporal window into the activity generated by a stimulus in a distributed, cascaded, semantic system (Laszlo & Federmeier, 2011). Therefore, it is reasonable to think that if semantic-based accounts of the ambiguity advantage are correct, ambiguous words would cause a larger N400 than unambiguous words, as the former would engage a larger amount of semantic activation during word recognition than the latter. In contrast, if ambiguity effects are located at the orthographic level of representation (i.e., ambiguous words benefit from having stronger orthographic-to-