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Semantic richness: The role of semantic features in processing spoken words

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ABSTRACT

A lexical decision and two visual world paradigm experiments are reported that investigated the role of semantic representations in recognizing spoken words. Semantic richness (NOF: number of features) influenced lexical decision reaction times in that semantically rich words (high NOF) were processed faster than semantically impoverished words (low NOF). Processing in the VWP was faster for high NOF words but only when an onset competitor was present in the display (target BREAD, onset competitor BRICK). Adding background speech babble to the spoken stimuli resulted in an advantage for processing high NOF words with and without onset competitors in the display. The results suggest that semantic representations directly contribute to the recognition of spoken words and that sub-optimal listening conditions (e.g., background babble) enhance the role of semantics.

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Introduction

In an episode of the well-known cartoon program The Simpsons, Homer offers Lisa something to eat:

> HOMER: Lisa, would you like a donut?
> LISA: No thanks. Do you have any fruit?
> HOMER: This has purple in it. Purple is a fruit.

While Homer might have unusual conceptions about fruits, many theories of semantic memory assume that it is useful to represent the meanings of objects through a set of features (e.g., *sugary*, *round*, *has filling* for the concept donut). However, what is less clear is whether such semantic representations affect the way spoken language is processed. Generally, models of spoken word recognition assume that processing begins by matching perceptual input to lexical representations and ends once a listener is able to extract the associated meaning. Since the process of computing the meaning of a spoken utterance must happen very fast in order to accommodate a typical speech rate of 100–150 words per minute (Mirman & Magnuson, 2009), semantic representations have the potential to be directly involved in processing spoken words by weighing which words get preferential activation. In the current investigation, we focus on the role of a word's semantics in the process of recognizing spoken words.

One approach used to investigate meaning activation in spoken word recognition is to infer semantic activation of a target word via semantic activation of phonological neighbors. This work builds on previous research showing that a phonological onset competitor of a spoken word is activated. In a series of cross-priming studies, Zwitserlood (1989) showed that when the auditory input is consistent with two words (e.g., /kap/ in kapitein, 'captain', and kapitaal, 'capital'), semantic priming effects are found for semantic associates of both words. When the listener receives the disambiguating input (i.e., the input after /kap/) only the best matching candidate remains activated. This suggests that listeners access the meaning of multiple

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candidates before they settle on the intended one. Connine, Blasko and Titone (1993) showed that the integrity of the phonological input (degree of match based on phonetic features) influences meaning activation of a target word (see also Connine, Titone, Blasko & Deelman, 1997). Using the visual world paradigm Allopenna, Magnuson, and Tanenhaus (1998) replicated the finding that phonological competitors (both onset and rhyme competitors) are activated during spoken word recognition. In other work, Yee and Sedivy (2006) showed that phonological activation of an onset competitor activates words that are related in meaning. For example, given the input 'logs', listeners looked at an object that was semantically related to an onset competitor 'key' ('key' is semantically related to the unpictured onset competitor 'lock'). The effects of semantic relatedness were observed at about 100 ms after target onset and suggest that the semantic interconnections among related words are active very early in processing (see also Huettig & McQueen, 2007). Other research in the spoken word domain has focused on the time course of activating different categories of semantic properties (Moss, McCormick, & Tyler, 1997; Yee, Huffstetler, & Thompson-Schill, 2011) or on the dynamics of activation for semantically related concepts (Mirman & Magnuson, 2009). The evidence from the above-mentioned studies indicates that when listeners activate phonological competitors, they also access semantic information about those competitors.

Another approach is to investigate directly the impact of a word's lexical semantics on spoken word recognition. For example, imageability has been shown to influence spoken word recognition (Tyler, Voice, & Moss, 2000; Tyler, Moss, Galpin, & Voice, 2002). Tyler et al. (2000) found that words with high imageability ratings were processed faster than words with low imageability ratings and that the effect of imageability was larger for words with a large number of cohort (onset) competitors. Our research uses the latter strategy in investigating activation of lexical semantics; specifically, we investigate if lexical semantics directly influence the time course of spoken word recognition.

Meaning and spoken word recognition

In the spoken word recognition literature, modular accounts assume that the activation of meaning and form occurs autonomously in stages. Such modularity is not supported by findings suggesting that continuous activation of lexical form combines with parallel activation of semantics during lexical access (Apfelbaum, Blumstein, & McMurray, 2011; Zwitserlood, 1989). Interactive accounts for how semantics influences word recognition would suggest that continuous activation of semantics contributes to processing of word forms. Two interactive models are presented below, starting with an overview of the Distributed Cohort Model (DCM) by Gaskell and Marslen-Wilson (1997; see also Gaskell & Marslen-Wilson, 1999) and the more recent interactive activation model by Chen and Mirman (2012).

In the spoken domain, the DCM (Gaskell & Marslen-Wilson, 1997, 1999) explicitly integrates semantics in its architecture and uses phonetic features as input. The DCM assumes that the phonology and semantics of words are represented in parallel and accessed simultaneously. There are no intermediate levels of representation; activation of lexical representations is done through direct mapping of phonetic feature input onto a distributed substrate for both phonology and semantics. Semantic knowledge in the model is represented through a vector of binary values (i.e., 0s and 1s), where 1 denotes the presence of a semantic property (see also Plaut and Shallice (1993) for this type of feature-based representation). When the model is presented with input that is compatible with multiple words (e.g., /gi/ for *gear* /gir/ and *geese* /gis/), form-based representations are activated as well as a frequency-weighted semantic 'blend' of the competitors. The model makes several predictions regarding the relationship between form and meaning access. First, the degree of semantic activation for a word depends on the number of onset-competitor words: a large number of phonological competitors will generate decreased or no semantic activation. This prediction has received some support; in an eye-tracking study, Apfelbaum et al. (2011) showed that words with a low number of onset competitors displayed greater semantic priming than words with a high number of competitors (see also Gaskell & Marslen-Wilson, 1997). However, even the high competitor group (with a mean of 24 competitors) showed significant semantic priming, which suggests that the structure for competition in DCM has a low ceiling set for semantic activation. A second prediction made by DCM is that semantic and lexical variables influence competition between word candidates. This allows for high frequency (see, for example, Dahan, Magnuson, & Tanenhaus, 2001) or semantically rich words to be preferentially activated.

One difficulty in developing models of word processing that include semantics is the issue of the how to define and represent semantic structure. This task is particularly difficult for at least two well documented reasons. First, relations between words and their meanings are largely arbitrary and different words or combination of words can reference a single concept (e.g., *cat, tom, domesticated feline creature* can all be tied to the same referent). A second difficulty relates to the fact that each individual has their own semantic representations which are rooted and shaped by a life-time of experiences. An ornithologist has richer semantic representations for the concept *robin* than an individual who is not engaged in studying birds. Therefore, a model should account for the variable structure of semantics or explain how semantic representations might change as an individual acquires more knowledge about a concept.

One approach for quantifying word meaning is to break down concepts into properties. On this view, concepts in the world have properties that are sensory (e.g., *has fur*, *meows, soft*), abstract (e.g., *is sad*), functional (e.g., *catches mice*), or taxonomic (e.g., *is animal*). Semantic access for a word could then be defined in terms of combined activation of multiple features. Thinking of concepts as arising from featural representations has served as an explanation for many empirical phenomena, such as semantic priming, categorization tasks (McRae, de Sa, & Seidenberg, 1997; Yee et al., 2011) and recognition of visual words (Pexman, Lupker, & Hino, 2002; Yap, Pexman, Hargreaves, & Huff, 2012). Furthermore, models using features as currency (Plaut, 2002; Plaut & Shallice, 1993) provide insight into how semantic memory works. It is unlikely that the repre-

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