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Effects of relative embodiment in lexical and semantic processing of verbs

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ABSTRACT

Research examining semantic richness effects in visual word recognition has shown that multiple dimensions of meaning are activated in the process of word recognition (e.g., Yap et al., 2012). This research has, however, been limited to nouns. In the present research we extended the semantic richness approach to verb stimuli in order to investigate how verb meanings are represented. We characterized a dimension of relative embodiment for verbs, based on the bodily sense described by Borghi and Cimatti (2010), and collected ratings on that dimension for 687 English verbs. The relative embodiment ratings revealed that bodily experience was judged to be more important to the meanings of some verbs (e.g., *dance*, *breathe*) than to others (e.g., *evaporate*, *expect*). We then tested the effects of relative embodiment and imageability on verb processing in lexical decision (Experiment 1), action picture naming (Experiment 2), and syntactic classification (Experiment 3). In all three experiments results showed facilitatory effects of relative embodiment, but not imageability: latencies were faster for relatively more embodied verbs, even after several other lexical variables were controlled. The results suggest that relative embodiment is an important aspect of verb meaning, and that the semantic richness approach holds promise as a strategy for investigating other aspects of verb meaning.

1. Introduction

To the skilled reader, the process by which word meaning is extracted from print feels quite simple. For visual word recognition researchers, however, explaining this process has proven considerably more complicated. One of the strategies that researchers have used to study lexical–semantic processing is to present individual words in tasks requiring simple decisions (e.g., the word/nonword judgment involved in the lexical decision task) and to examine whether different properties of the words themselves (their meaning, syntax, etc.) influence responses in systematic ways. If word recognition behavior is influenced by those properties, then inferences can be made about the processes involved in visual word recognition.

For instance, a great deal has been learned about lexical–semantic processing by examining the effects of words' *semantic richness* (for a review see Pexman (2012)). That is, there is variability in the amount of semantic information associated with different words, and this variability can be defined in different ways, as a function of the descriptions of word meaning that have been proposed. Further, this variability is related to behavior in visual word recognition tasks, such that responses are typically faster for semantically richer words. Semantic richness effects are consistent with the principle that when it comes to semantic activation in lexical processing, "more is better" (Balota, Ferraro, & Connor, 1991, p. 214).

According to variants of the embodied cognition framework, knowledge gained through perceptual (e.g., Paivio, 1991) and sensorimotor or bodily experience (e.g., Barsalou, 1999) are important components of word meaning. The embodied cognition framework holds that sensorimotor systems are integral to conceptual knowledge, such that sensorimotor states activated when we experience the world are also involved in simulation when we think about the world (e.g., Barsalou, 2008; Gallese & Lakoff, 2005). Thus, even when cognition is off-line, or decoupled from the environment, it is grounded in sensory processing and motor control (Wilson, 2002).

Support for the embodied cognition framework has been provided by studies showing that performance in visual word recognition tasks is facilitated for words that refer to concepts that are easily imageable (imageability effects; e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004) or with which the human body can easily interact (body–object-interaction (BOI) effects; Hargreaves et al., 2012; Siakaluk, Pexman, Aguilera et al., 2008; Siakaluk, Pexman, Sears et al., 2008; Tousignant & Pexman, 2012). These semantic richness effects certainly do not explain all of the variance in lexical–semantic processing, and they can be observed alongside other semantic richness effects that

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are less obviously derived from the embodied cognition framework, such as semantic neighborhood effects (Buchanan, Westbury, & Burgess, 2001). As such, work using the semantic richness approach suggests that word meaning is not fully explained by models that assume that one type of information comprises the basic unit of meaning (e.g., Burgess & Lund, 1997; McRae, de Sa, & Seidenberg, 1997). Rather, word meaning seems to be multidimensional, consistent with a number of recent proposals (e.g., Barsalou, Santos, Simmons, & Wilson, 2008; Dove, 2009).

Semantic richness effects have been explained in terms of semantic feedback activation (e.g., Hino & Lupker, 1996; Pexman, Lupker, & Hino, 2002) in a fully-interactive visual word recognition system that includes separate but interconnected sets of units representing orthographic, phonological, and semantic information. That is, processing in the model involves feedforward and feedback activation between units in order that the system settles into a stable state (e.g., Harm & Seidenberg, 2004). Words with richer semantic representations are assumed to generate more semantic activation; visual recognition of words associated with relatively more semantic information involves activation of more semantic units (e.g., for concrete words in the model of Plaut & Shallice (1993)) and more efficient neural processing (e.g., for words with a high number of associates, in the fMRI study of Pexman, Hargreaves, Edwards, Henry, and Goodyear (2007)).

Importantly, increased semantic activation can have different consequences for lexical processing, as a function of task demands. That is, task demands shift focus around the visual word recognition system in terms of the kind of information on which responses are primarily based. In a lexical decision task, it is argued that the activity in orthographic representations is the primary basis for responding (Balota et al., 1991; Hino, Lupker, & Pexman, 2002). In order to explain the fact that BOI and imageability effects have been observed in lexical decision it is assumed that these words evoke stronger semantic activation (because they are associated with relatively more sensorimotor information; Pexman et al., 2002), which provides stronger feedback activation from semantics to orthography and, as a result, stronger evidence for a "word" response. In a naming task, it is assumed that stronger semantic activation would provide stronger feedback activation to phonological representations, which are the primary basis for responding when a vocal response is required (e.g., Bennett, Burnett, Siakaluk, & Pexman, 2011). Lastly, in a task that is more directly focused on semantic activation per se (e.g., a meaning classification task), processing would be facilitated for semantically richer concepts, because faster settling of semantic representations is associated with words with richer semantic representations (e.g., Pexman, Holyk, & Monfils, 2003; Siakaluk, Pexman, Sears et al., 2008).

While the semantic richness approach has provided important clues about dimensions of word meaning and the nature of lexical–semantic processing, the approach has only been applied to noun stimuli. Thus, we now know much about the multidimensional structure of semantic memory for nouns, particularly concrete nouns (e.g., Amsel, Urbach & Kutas, 2013; Grondin, Lupker & McRae, 2009; Hargreaves & Pexman, 2014; Pexman, Hargreaves, Siakaluk, Bodner, & Pope, 2008; Yap, Pexman, Wellsby, Hargreaves, & Huff, 2012; Yap, Tan, Pexman, & Hargreaves, 2011). The goal of the present study was to investigate the structure of semantic memory for verbs by extending the semantic richness approach to verb stimuli. Although there is reason to believe that semantic richness effects could be observed for verbs, there is also reason to believe that verbs may be represented differently than nouns.

The notion that nouns and verbs may be associated with different semantic information has been explored in a number of lexical decision studies (e.g., Cordier, Croizet, & Rigalleau, 2013; Kauschke & Stenneken, 2008; Rösler, Streb, & Haan, 2001). These studies have generally reported a noun advantage; that is, faster responses to nouns than to verbs. One suggested explanation for this effect is that nouns tend to be more imageable than verbs (Allport & Funnell, 1981). Another suggestion made by Cordier et al. (2013) is that semantic feedback or semantic activation might be lower for verbs than for nouns. They compared lexical processing for French nouns and verbs, and in addition to showing the standard noun advantage, did not find that any semantic variables predicted lexical decision latencies for verbs. They acknowledged that their small sample size (only 26 verbs) could have limited power to detect semantic effects for their stimuli.

Only a handful of other studies have examined the influence of lexical–semantic variables for verbs. In one of the few studies to separately examine lexical processing of verbs, Colombo and Burani (2002) showed that word frequency and age of acquisition (AoA) were both related to lexical decision latencies for Italian verbs. That is, latencies were faster for more frequent verbs and for verbs rated as having been learned earlier in life. Somewhat different findings were reported by Boulenger, Décoppet, Roy, Paulignan, and Nazir (2007) with French verbs; in their lexical decision experiment only frequency was related to action verb latencies, with AoA not accounting for any additional variability in latencies.

Thus, the research to date offers very little evidence that semantic richness influences lexical processing of verb stimuli. However, there is strong evidence that recognition of *goal-directed action verbs* evokes sensory and motor processing. For instance, Hauk, Johnsrude, and Pulvermuller (2004) presented participants with action words referring to arm, face, or leg actions (e.g., *pick*, *lick*, *kick*). Passive viewing of these verbs was associated with activation in corresponding motor and premotor areas linked to arm, face, and leg movements. Ruschemeyer, Brass, and Friederici (2007) also examined the neural correlates of lexical processing for action verbs using fMRI, and compared activation associated with German motor verbs and abstract verbs. Results showed greater activation in motor and somatosensory cortices for motor verbs, suggesting, again, a functional relationship between lexical processing of action verbs and the sensorimotor system. Similarly, Nazir et al. (2008) showed that making lexical decisions to action words disrupted concurrent reaching movements, suggesting overlap between the lexical and motor systems.

More compelling evidence for this link is provided by a recent study reported by Repetto, Colombo, Cipresso, and Riva (2013). In the Repetto et al. study participants made semantic decisions (concrete/abstract) to hand-related action verbs (e.g., *catch*, *peel*) and more "abstract" verbs (e.g., *forget*, *terrify*). The authors used rTMS to disrupt processing in the hand portion of primary motor cortex, and showed that this slowed semantic decisions for hand-related action verbs but not for abstract verbs. As such, they concluded that the motor cortex plays a functional role in comprehension of action verbs, consistent with a strong version of the embodied cognition framework (e.g., Gallese & Lakoff, 2005).

These studies suggest that the motor system is important in processing the meanings of specific, goal-directed action verbs, and reflect the focus on action that has characterized much of the empirical and theoretical work on embodied cognition: "In this perspective the body is always considered as an *acting* body" (Borghi & Cimatti, 2010, p. 763). Importantly, Borghi and Cimatti point out that meaning derived through embodiment is grounded in multiple ways, not only through action; the body could play a role in language and conceptual processing that goes beyond its involvement in specific, goal-directed actions (e.g., *pick*, *peel*). Borghi and Cimatti argue that body perception could be construed as more than overt, voluntary actions, to involve passive movements and internal sensory experience (e.g., proprioceptive experience), and that these sources could also ground meaning. A body sense does not require agency but a feeling of being an individual body, situated in place and time, experiencing multisensory input. Further, the bodily sense is not an all-or-none construct but, instead, one that develops by degrees.