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Manipulability impairs association-memory: Revisiting effects of incidental motor processing on verbal paired-associates

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ABSTRACT

Imageability is known to enhance association-memory for verbal paired-associates. High-imageability words can be further subdivided by manipulability, the ease by which the named object can be functionally interacted with. Prior studies suggest that motor processing enhances item-memory, but impairs association-memory. However, these studies used action verbs and concrete nouns as the high- and low-manipulability words, respectively, confounding manipulability with word class. Recent findings demonstrated that nouns can serve as both high- and low-manipulability words (e.g., CAMERA and TABLE, respectively), allowing us to avoid this confound. Here participants studied pairs of words that consisted of all possible pairings of high- and low-manipulability words and were tested with immediate cued recall. Recall was worse for pairs that contained high-manipulability words. In free recall, participants recalled more high- than low-manipulability words. Our results provide further evidence that manipulability influences memory, likely occurring through automatic motor imagery.

1. Introduction

Imageability, the ease by which a word evokes a mental image, is known to enhance association-memory for verbal paired-associates (e.g., Madan, Glaholt, & Caplan, 2010; Paivio, 1971). One hypothesis proposed to account for this phenomenon is the dual-coding theory (Paivio, 1971, 1986, 2007), which suggests that low-imageability, i.e., abstract, words are encoded through only a verbal 'code', while high-imageability, i.e., concrete, words can be encoded through both verbal and imaginal 'codes'. Engelkamp and Zimmer (1984) proposed an extension of the dual-coding theory, to include additional motor 'code'. However, in studying the effects of motor processing on memory, researchers had previously compared action verbs with concrete nouns (see Engelkamp & Cohen, 1991, for a review) confounding motor processing with noun versus verb (i.e., word class; see Madan & Singhal, 2012a,b, for detailed discussions).

It is problematic that previous studies confounded word class with motor processing, as it is known that word class also influences memory, including association-memory (e.g., Earles & Kersten, 2000; Earles, Kersten, Turner, & McMullen, 1999; Gupton & Frincke, 1970). Of particular relevance, Dilnika (2002) found that participants were worse at remembering verb–verb pairs than noun–noun pairs, independent of any motor-related effects. This issue of word class was first identified by Saltz (1988), who suggested that semantically related nouns could be used as the motor-conducive stimuli (e.g., HOP to RABBIT). Further, Helstrup (1989, 1991) directly suggested that verb pairs may be more difficult to integrate than noun pairs (also see Kormi-Nouri, 1995). To partially justify this confound, it is important to note that this body of research on motor processing and memory developed around the enactment effect, where memory is enhanced for phrases that described actions performed by the subject, relative to phrases that were only read, heard, or were performed by the experimenter (e.g., Cohen, 1981; Engelkamp & Cohen, 1991; Madan & Singhal, 2012c). Due to this original focus, it is understandable that researchers focused on using verbs. Additionally, researchers in the 1980s were unaware that other solutions were available, as Engelkamp (1986) specifically states that "concrete nouns, for instance, cannot per se be encoded via motor activity".

Given recent advances, we are now able to design studies that better match stimuli sets for other item properties. Briefly, neuroimaging evidence indicates that nouns and verbs are processed differently within the brain (e.g., Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Shapiro & Caramazza, 2003). There is also evidence that concrete and abstract nouns (i.e., high- vs. low-imageability) are processed through different brain regions (Binder, Westbury, McKiernan, Possing, & Medler, 2005). Nonetheless, of greatest relevance are findings that

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high-manipulability words, which are a subset of concrete nouns, engage motor regions of the brain more than low-manipulability words (Buxbaum & Saffran, 2002; Just, Cherkassky, Aryal, & Mitchell, 2010; Rueschemeyer, van Rooij, Lindemann, Willems, & Bekkering, 2010) Specifically, both high-manipulability and low-manipulability words (e.g., CAMERA and TABLE, respectively), are concrete nouns that represent objects. However, high-manipulability words refer to objects that can easily be functionally interacted with using one's hands, while low-manipulability words are not. Note that manipulability specifically refers to hand–object interactions, unlike body–object interaction (BOI; e.g., Siakaluk, Pexman, Aguilera, Owen, & Sears, 2008; Wellsby, Siakaluk, Owen, & Pexman, 2011) which encompasses interactions using any body part, though both are based on motor-related processing.

Studies have found that motor-related words can interfere with overt motor movements, even when the motor properties are not directly attended to, which we refer to as 'automatic motor processing,' demonstrating the functional importance of motor-related processing on cognition. For instance, Glover, Rosenbaum, Graham, and Dixon (2004) demonstrated that when picking up a wooden blocks and silently reading a word, participants used a larger grip aperture if the word represents a relatively larger object (e.g., APPLE). If the word represents a smaller object (e.g., GRAPE), a smaller grip aperture is used (also see Gentilucci & Gangitano, 1998). Additionally, activation of motor regions through either overt movements (Shebani & Pulvermüller, 2013) or artificially via TMS (Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005) impairs the processing of motor-related words that involve the same effector, e.g., arm-related words and arm movements interfere, but leg-related words and leg movements can occur in parallel unhindered. These interactions and impairments demonstrate that motor processing is a relatively sequential process. See Pulvermüller (2005) and Madan and Singhal (2012a) for related reviews.

Demonstrating the validity of manipulability as a word property, several studies have found that words that represent objects that can be functionally interacted with, i.e., high-manipulability words, are processed differently within the brain than words that cannot be functionally interacted with, i.e., low-manipulability words (e.g., CAMERA and TABLE, respectively; Buxbaum & Saffran, 2002; Just et al., 2010; Rueschemeyer et al., 2010). Given this important result, it is plausible that manipulability can affect memory, and the word class confound can be avoided. Madan and Singhal (2012b) tested this hypothesis directly, using a between-subjects design. One group of participants was presented with high- and low-manipulability words, one at a time, and asked to judge if the word represented an object that the participant had seen in the past three days ('personal experience' group). This judgment task was followed by a surprise free recall task, where participants were asked to recall any words they could from the preceding task. Madan and Singhal (2012b) found that participants in the personal experience group recalled more high- than low-manipulability words. Another group of participants was asked to judge the length of the words to be odd or even ('word length' group), but was otherwise given the same task. Here participants also recalled more high- than low-manipulability words. A third group was asked to rate the words on the functionality, i.e., if the object represented by the word can be functionally manipulated ('functionality' group). Unlike the other two groups, participants in the functionality group recalled more low- than high-manipulability words. Madan and Singhal (2012b) suggest that there is a manipulability that automatically enhances memory. However, when manipulability is directly attended to, as in the functionality group, controlled motor-related processes override this automatic bias. Montefinese, Ambrosini, Fairfield, and Mammarella (2013) also tested for effects of manipulability on memory. Specifically, Montefinese et al. (2013) asked participants to intentionally study high- and low-manipulability verbs, followed by an old/new recognition test. Participants were found to demonstrate a bias to endorse high-manipulability verbs as 'old,' despite demonstrating no difference in memory. This bias to endorse high-manipulability words is suggestive of an influence of motor processing on memory, but perhaps only a weak effect when items are encoded intentionally and tested with recognition.

Here we tested whether manipulability has an effect on association-memory. The presence of such an effect would indicate an automatic influence of motor-related processing on how words are processed, integrated into an association, and remembered. Additionally, any effect of manipulability will provide further evidence for theories of embodied cognition and suggest that manipulability is an important additional item-property to be considered when testing for stimulus properties that influence memory. Engelkamp (1986) was also interested in the effect of motor processes on association-memory, comparing memory for pairs of concrete nouns ('visual imagery') to memory for pairs of action verbs ('motor imagery'); however, this comparison was confounded by differences in word class. Here an impairment of association-memory due to motor imagery was found, with the verb ('motor imagery') pairs being recalled to a lesser degree than the noun ('visual imagery') pairs. (These results are replicated in Engelkamp, Mohr, & Zimmer, 1991, and discussed further in Engelkamp, 1988, 1995) However, Lippman (1974) conducted a similar study using *only* verb–verb pairs. Specifically, Lippman (1974) had participants study pairs consisting of verbs that were either high in enactive imagery (HH; e.g., MOW, WADE), low in enactive imagery (LL; e.g., BEGIN, OBEY), or a mix (HL or LH). Lippman (1974) found that memory was enhanced when either the cued recall probe or target was high in enactive imagery, as well the combination of both the probe and target was high in enactive imagery. Taken together, these results are suggestive of an enhancement of association-memory due to motor processing. Thus, in this case where word class is not a confound, association-memory was enhanced due to motor processing. Supporting this result, Harris, Murray, Hayward, O'Callaghan, and Andrews (2012) presented images of high- and low-manipulability objects in a rapid serial visual presentation task. While repetition blindness was observed for the low-manipulability objects, a repetition advantage was found for high-manipulability objects.

Given these contradictory findings, it is unclear whether manipulability will enhance or impair association-memory. If manipulability functions similar to imageability, where motor representations can be used to integrate information, association memory should be enhanced due to manipulability (association-memory enhancement hypothesis). This hypothesis is given credence by the results of Lippman (1974), where participants studied verb–verb pairs that varied in enactive imagery. If this result generalizes to nouns, we would predict that association-memory should be enhanced due to manipulability. In contrast, since hand-related motor actions must occur sequentially, unlike visual imagery, it is possible that motor imagery, and thus manipulability, will impair association-memory (association-memory impairment hypothesis). Engelkamp (1986) compared memory for pairs of concrete nouns and action verbs and found worse association-memory due to motor processing. If these results generalize afterword class is no longer confounding the degree of motor processing, association-memory should also be impaired due to manipulability. In the case of either hypothesis, a caveat must be made: the size of the observed effect will be small in magnitude. As manipulability is nested within imageability, both high- and low-manipulability words are high in imageability. Thus, while imageability has been shown to have a large effect on recall (e.g., Madan et al., 2010), variability in manipulability is serving as inter-item 'noise' in these studies, and both high- and low-manipulability words are being recalled well. The aim of the current study is to determine if manipulability is causing a relative enhancement or impairment of association-memory, above the enhancement known to be produced by imageability.

In the current study, participants intentionally studied pairs of words that were either both high-manipulability, both low-manipulability, or consisted of one word of each type. Participants were then tested using cued recall, where they were given one of the paired words and asked to recall its associate. It is important to note that cued recall is not a direct test of association-memory, it is also influenced by item-memory. For instance, if a word property improved item retrievability, but not