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Testing the embodied account of object naming: A concurrent motor task affects naming artifacts and animals

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ABSTRACT

Embodied theories of object representation propose that the same neural networks are involved in encoding and retrieving object knowledge. In the present study, we investigated whether motor programs play a causal role in the retrieval of object names. Participants performed an object-naming task while squeezing a sponge with either their right or left hand. The objects were artifacts (e.g. hammer) or animals (e.g. giraffe) and were presented in an orientation that favored a grasp or not. We hypothesized that, if activation of motor programs is necessary to retrieve object knowledge, then concurrent motor activity would interfere with naming manipulable artifacts but not non-manipulable animals. In Experiment 1, we observed naming interference for all objects oriented towards the occupied hand. In Experiment 2, we presented the objects in more 'canonical orientations'. Participants named all objects more quickly when they were oriented towards the occupied hand. Together, these interference/facilitation effects suggest that concurrent motor activity affects naming for both categories. These results also suggest that picture-plane orientation interacts with an attentional bias that is elicited by the objects and their relationship to the occupied hand. These results may be more parsimoniously accounted for by a domain-general attentional effect, constraining the embodied theory of object representations. We suggest that researchers should scrutinize attentional accounts of other embodied cognitive effects.

1. Introduction

Historically, theories of cognition have maintained that the brain's representations of the objects, people, and events we encounter are symbolic, amodal, and independent of the sensory and motor systems that we use to interact with the world. Such theories dominate the cognitive psychological literature in which most models of cognitive processes include—either implicitly or explicitly—symbolic representations. The types of theoretical cognitive constructs arising from this line of thought include different modules of visual processing (e.g. structural encoding, see Bruce & Young, 1986) and separate memory stores for different types of information (e.g. Humphreys, Lamote, & Lloyd-Jones, 1995).

Recently, however, theories of embodied cognition have provided an alternative to amodal theories, proposing instead that the way in which an organism interacts with the environment constrains the cognitive processes that underlie thought and behavior (Lakoff & Johnson, 1999). Though as of yet there is no standard, unified theory of embodied cognition, models of embodied cognition generally propose that simulations of sensory-motor activity (e.g. visual, auditory, and sensory-motor imagery), situated action (e.g. experiences of performing motor acts under different conditions), or bodily states (e.g. experiences of arousal and other effects of emotional experience), implemented in their respective modal brain systems, underlie cognitive process (see Barsalou, 2008 for a review of evidence in favor of embodied theories in perception, action, memory, language, social cognition, problem solving and reasoning, and development). Further, these theories suggest that the representation of the external world is built primarily from the properties that afford action (e.g. object affordances, see Gibson, 1986). One of the strengths of embodied theories is that they offer a way of understanding the organization of human perception and action.

Embodied theories of cognition make important predictions about the role of sensory-motor programming in cognitive tasks. Specifically, these theories posit that a) simulations of sensory-motor processing form the basis of object representations, and b) these representations underlie our ability to identify objects. Thus, embodied theories predict activity in the sensory-motor association cortices even when there is no specific instruction to perform actions on visually presented objects. Chao and Martin (2000) provide evidence that this is the case. In a passive viewing task, functional magnetic resonance imaging (fMRI) revealed activity in the left ventral premotor cortex and the left posterior parietal cortex in response to pictures of tools but not animals

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(see also Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Gerlach, Law, & Paulson, 2002).

Importantly, this neuroimaging evidence is correlational (i.e., epiphenomenal); it simply suggests that modal representations are activated when viewing manipulable objects. It remains unclear whether these simulations play a *causal* role in behavior, facilitating action execution, action understanding, or object naming. Indeed, co-activation of sensory-motor representations during the visual presentation of manipulable objects may simply reflect associative, Hebbian learning, in which visual representations and sensory-motor representations become associated because we typically act on objects we can see. Critically, theories of embodied cognition propose that sensory-motor representations play a causal role in cognitive tasks (e.g. object identification and action understanding). Assessing the functional role of sensory-motor representations in cognitive tasks remains one of the most important goals of cognitive psychological research.

This issue has not received much attention. To test whether sensory-motor representations play a causal role in object naming it is necessary to disrupt the simulations that are proposed to underlie object representations. To test this behaviourally, Witt, Kemmerer, Linkenauger, and Culham (2010) had participants name pictures of tools or animals while squeezing a ball. The tool-handles and the animal-heads were oriented towards or away from the occupied hand. The authors showed that naming was slower for the tools that were oriented towards the occupied hand. Naming times did not differ for the animals. These results suggest that a concurrent motor task interfered with the ability to name tools specifically, leading the authors to conclude that motor simulations play a causal role in object naming. This finding provides the strongest support for embodied object representations.

However, this conclusion was not supported by another study. Pecher (2012), attempting to extend Witt et al.'s (2010) investigations, tested the hypothesis that interfering with motor simulations should affect working memory processes related to manipulable objects but not non-manipulable objects. Pecher had participants engage in a complicated hand and finger movement sequence during working memory tasks for pictures and words denoting manipulable and non-manipulable objects. She showed that the concurrent motor task affected working memory for both manipulable and non-manipulable objects. This finding is inconsistent with embodied accounts of object representations. The author speculated that a domain-general, non-modality specific effect underlies her results, such as interference at the level of the visuospatial sketchpad (in Baddeley's working memory model; Baddeley & Hitch, 1974). This result challenges the strong form of the embodied cognition hypothesis.

2. Experiment 1

Whether a concurrent motor task interferes with object processing is not clear. In the present study we investigated the causal role of sensory-motor simulations in object naming. We adopted a paradigm similar to Witt et al. (2010) but extended the methods in a number of ways. First, the participants in Witt et al. (2010) were instructed to squeeze a sponge but were free to hold their hands in any position (most choosing to rest them on the arms of the chair). This introduces variability due to hand position and introduces a confound with respect to the location of the hand in the visual field (i.e., when squeezing with the right hand, the hand and sponge are both visible in the right visual field and vice versa). Thus, in their study, it is unclear whether any effects are the result of the concurrent motor task per se, or to the differences in the visual field of the occupied hand. To remove this confound we mounted a sponge above the edge of the table in front of the computer screen (and therefore in view of the participants), centered at the participant's midline. This ensured that the position of the participant's hand and the sponge were held constant, eliminating the confound of the concurrent motor task and which visual field the occupied hand falls in. Second, Witt et al. (2010) presented participants with profile views of objects at 0° with respect to the horizon. We sought to reduce ambiguity of afforded action by orienting the objects 45° from their initial upright position towards the right or the left. Subjectively, this increased the sense that each object afforded a left- or a right-hand grasp.

We predicted that, if sensory-motor simulations are causally involved in object naming, then pre-occupying the sensory-motor system by squeezing a ball with a hand should affect the ability to name objects that can be grasped with the occupied hand (artifacts) but not non-manipulable objects (animals).

2.1. Method

2.1.1. Participants

One hundred twenty-four participants participated in Experiment 1 ($N = 61$ right-hand squeeze group, $N = 49$ females, $M = 23.69$, $SD = 6.64$ years old; $N = 63$ left-hand squeeze group, $N = 51$ females, $M = 19.97$, $SD = 2.81$ years old). All participants had normal or corrected-to-normal vision and English as a first language. 102 participants were right-handed, 10 were left-handed, and 12 reported being ambidextrous. Participant demographics are represented in Table 1.

2.1.2. Materials

Thirty-seven greyscale photographs of natural objects (i.e. animals) and thirty-four photographs of man-made objects (i.e. tools and other human artifacts) were taken from the set developed by Salmon, Filliter, and McMullen (2010). Greyscale objects were used to eliminate any incidental cues to both grasping (e.g. wooden protrusions and darkly dyed rubber) and identity (e.g. colored spots or stripes and the color of metals) that may be learned through experience and that may facilitate object naming in the absence of processing object form. Such cues could facilitate or bias naming differently in the animal and artifact stimuli used here, and are therefore important to remove. Using GIMP 2.0 (GNOME Foundation, Groton, MA) each object was rotated such that the handle (for the man-made objects) or tail-ends (for the natural objects) were oriented towards the right or left at approximately 45° from upright (see Fig. 1). In a pilot test, we presented participants ($N = 3$) with graspable, toy versions of common animals (e.g. horse, chicken). The items were placed on the table in front of the participants and they were instructed simply to pick up the object. In every case, participants grasped the toys by their tail-ends towards the occupied hand (and not their heads). This suggests that presenting animals with their tails towards the occupied hand would increase the likelihood of activating a motor simulation. Thus, unlike Witt et al. (2010), we presented the objects with their handles or their tail-ends towards the occupied hands, considering these to be the 'graspable' ends. Sitting at approximately 60 cm from the monitor the stimuli subtended approximately 9.5° of visual angle.

Each object in this set is associated with mean ratings of familiarity, age of acquisition, and manipulability according to two different criteria (see Salmon et al., 2010). It was not possible to match the object categories (artifacts and animals) on the traits of familiarity and age of acquisition. These variables likely influence overall naming for both categories of objects. Importantly, an independent samples t-test showed that the artifacts were rated as more manipulable than the animals, $p < .01$. See

Table 1
Summary of sample from Experiment 1 ($N = 124$). The number of participants is listed in each cell by participant handedness and by right- and left-hand squeeze groups.

	Left-hand squeeze group	Right-hand squeeze group
Handedness		
Ambidextrous	6	6
Left	7	3
Right	50	52