How to change your memory of an object with a posture and a verb

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Abstract

According to grounded cognition, the format of representation of knowledge is sensorimotor. This means that long-term memory shares processing resources with the sensorimotor system. The main objective of this work is to provide new evidence in favour of two claims from the embodied cognition framework: (1) memory is grounded on the sensorimotor system, that is, memory shares processing resources with the sensorimotor system, and (2) memory serves at least in part to support action. For this purpose, the present experiment aimed to show that the action context modulates the motor simulation and, consequently, the memory of manipulable objects. Participants were presented with short phrases comprising the name of a manipulable object, and an action verb (“To take a cup”) or an attentional verb (“To see a cup”). During this phase, they had to put their hands in front of them in the control condition, whereas they had to keep them behind their back in the interfering condition. A cued recall test followed after a short distractive letter-matching task, with the verbs serving as cues. Results showed that memory of the words denoting manipulable objects was impaired by the interfering posture when associated with an action verb, but not when associated with an attentional verb. This suggests that a context which does not favour action interferes with motor simulation and thus decreases the memory of manipulable objects. These results provide strong evidence for a grounded account of memory and language.

Keywords

Grounded cognition; long-term memory; action; mental model; language

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Introduction

In recent decades, the format of representation of knowledge has been one of the most debated questions in cognitive science. According to grounded cognition, memory retrieval should be seen as a sensorimotor simulation, that is, a re-enactment of the sensorimotor activity at encoding (Barsalou, 1999; Versace et al., 2014; see Matheson & Barsalou, 2017). This suggests that the format of representation of knowledge is sensorimotor and that long-term memory shares processing resources with the sensorimotor system. The activation of the concept of a manipulable object (such as a hammer) from long-term memory is claimed to involve not only the reinstatement of the visual or auditory patterns of activation related to previous experiences with the object but also the reinstatement of the motor patterns related to its use, that is, their affordances. Glenberg (1997) underlined the importance of motor system in memory, claiming that the main function of knowledge is to support action. He proposed that memory encodes the

environment in terms of affordances and that the subsequent simulation of these affordances aims to support action. The affordance of an object is defined here, along with Glenberg’s ideas, as the potential actions that an organism can perform on it, given the actual state of the object, the prior history of the organism’s interactions with this object, and the

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organism's ability to act. Given this background, the main aim of the present work is to provide new evidence in favour of two claims from embodied cognition theories (Wilson, 2002): (1) long-term memory is grounded on the sensorimotor system, that is, memory shares processing resources with the sensorimotor system, and (2) long-term memory serves at least in part to support action.

In support of these ideas, many studies have shown via the stimulus–response compatibility paradigm that the viewing of a manipulable object potentiates motor actions associated with the use of that object (e.g., Bub, Masson, & Cree, 2008; Rueschemeyer, Pfeiffer, & Bekkering, 2010; Tucker & Ellis, 1998, 2004; van Elk, van Schie, & Bekkering, 2009). Tucker and Ellis (2004) asked their participants to indicate whether an object (depicted in a picture) was a man-made or a natural object. Half of the objects could be grasped with either a precision grip or a whole-hand grip. The response could be made either with a precision grip device or with a whole-hand grip device. Faster reaction times were found when the response and the object grip were compatible. Numerous neuroimaging experiments have shown that viewing pictures of manipulable objects activates motor regions more than non-manipulable objects or animals (see Chouinard & Goodale, 2010, for a meta-analysis; see Noppeney, 2008, for a review). Importantly, similar stimulus–response compatibility effects (Bub et al., 2008; Tucker & Ellis, 2004; but see Flumini, Barca, Borghi, & Pezzulo, 2015) and motor activations (e.g., Carota, Moseley, & Pulvermüller, 2012; Rueschemeyer, Pfeiffer, et al., 2010; Rueschemeyer, van Rooij, Lindemann, Willems, & Bekkering, 2010) have been observed when words denoting manipulable objects were presented instead of pictures. This suggests that the motor simulation arises not only from the visual properties of the object but also from the activation of the concept from memory. Nevertheless, the main limitation of these paradigms is that the motor activations could be the mere consequences of an activation cascade, without any role in concept representation (Mahon & Caramazza, 2008).

To assess more directly the role of motor simulation in the representation of manipulable objects, several studies have instead addressed the effect of motor interference on the processing of manipulable objects, as suggested by Mahon and Caramazza (2008). First, it seems that a motor impairment following a stroke (Buxbaum & Saffran, 2002; Myung et al., 2010) or a transcranial magnetic stimulation protocol (Pobric, Jefferies, & Lambon Ralph, 2010) provokes a deficit in knowledge or processing of manipulable objects. However, it is important to note that other studies have not demonstrated such effects (Garcea, Dombovy, & Mahon, 2013; Kemmerer, Miller, Macpherson, Huber, & Tranel, 2013; Negri et al., 2007; Reilly et al., 2014). A few studies have investigated the effect of interfering movements on the conceptual processing of manipulable objects (e.g., Bub, Masson, & Lin, 2013; Witt, Kemmerer,

Linkenauger, & Culham, 2010; Yee, Chrysikou, Hoffman, & Thompson-Schill, 2013). For instance, Witt et al. (2010) found that squeezing a ball in one hand made it more difficult for healthy participants to name tools whose handles faced the squeezing hand. These studies show that the retrieval of manipulable object knowledge from long-term memory involves the retrieval of motor information, which is impaired by a motor interference and leads to a decrease in observed performances. Nonetheless, Matheson, White, and McMullen (2014) found the same interference with manipulable objects as well as with non-manipulable objects, suggesting that this effect might not be specific to action-related objects. Concerning the effect of motor interference on short-term memory, results are again controversial (see Zeelenberg & Pecher, 2016, for review). On one hand, several studies by Guérard and colleagues (Downing-Doucet & Guérard, 2014; Guérard, Guerrette, & Rowe, 2015; Lagacé & Guérard, 2015) have shown that the recall of manipulable objects decreases when learned while performing an incongruent interfering motor task. On the other hand, Pecher and colleagues failed to find such effects (Pecher, 2013; Pecher et al., 2013; Quak, Pecher, & Zeelenberg, 2014). This inconsistency could be explained by the fact that the motor system may not be necessary to maintain visuospatial information in short-term memory. Concerning the effect of motor interference on long-term memory, only very few attempts have been made up to now (Dutriaux & Gyselinck, 2016; van Dam, Rueschemeyer, Bekkering, & Lindemann, 2013). Dutriaux and Gyselinck (2016) searched for a way to modulate the motor simulation at encoding and see whether it affects the motor simulation at retrieval. As stated earlier, Glenberg (1997) proposed that the world is encoded in terms of affordances, which are dependent on the organism's ability to act. Thus, if the simulation of affordance is involved in the representation of manipulable objects, a constraining posture should interfere with the affordance and thus decrease the memory of manipulable objects. Based on this reasoning, Dutriaux and Gyselinck (2016) used two different postures. The control posture, in which the participants' hands were free in front of them, was chosen to favour free-hand actions and thus motor simulation. The interfering posture requires the participants to keep their hands behind their back to interfere with action possibilities and thus with the supposed motor simulation of affordance. This posture has been chosen because it has been found to have a negative effect on motor simulation (e.g., Ambrosini & Costantini, 2017; Sirigu & Duhamel, 2001). Dutriaux and Gyselinck (2016) showed that keeping one's hands behind one's back interferes with the long-term memory of pictures as well as words denoting manipulable objects, but did not interfere with the memory of non-manipulable objects. This specific interfering effect of posture on action material, referred to as the *Postural Interference effect* (PI effect), clearly shows that conceptual

memory and the motor system share processing resources and that long-term memory serves at least in part to support action.

This experiment might be taken as evidence that motor simulation depends on whether the context (i.e., the posture) is more or less conducive to action. Several other studies are consistent with this idea. For instance, previous experiments have suggested that an interfering posture (e.g., Sirigu & Duhamel, 2001) can reduce motor simulation. In the same vein, when an object is presented in the non-reachable space, the motor simulation is reduced (Cardellicchio, Sinigaglia, & Costantini, 2011; Costantini, Ambrosini, Scorolli, & Borghi, 2011). Given that motor simulation has been shown with pictorial as well as with verbal materials (e.g., Dutriaux & Gyselinck, 2016; Tucker & Ellis, 2004), providing a non-action linguistic context might be able to modulate the motor simulation of affordance in a similar way. The objective of the present study was to explore this idea by modulating the action context with both posture and language. A number of researchers have proposed that the comprehension of a sentence requires a sensorimotor simulation of its meaning as a whole (e.g., Barsalou, 1999; Glenberg & Robertson, 1999), which could be seen as a sensorimotor situation model (see “Discussion” section). It follows that the sensorimotor simulation of a concept is flexible in that its simulation should depend on the linguistic context of the sentence. That is, the motor simulation should vary, depending on to what extent the linguistic context emphasises action or not (Masson, Bub, & Warren, 2008; Moody & Gennari, 2010; van Dam, Brazil, Bekkering, & Rueschemeyer, 2014). In support of this hypothesis, a functional neuroimaging study by van Dam et al. (2014) showed that the motor activity related to the reading of a word denoting a manipulable object depends on whether the typical use of the object is emphasised by the linguistic context. Masson et al. (2008) presented their participants with sentences containing a manipulable object and a verb. The verb was either an “attentional verb,” that is, without any direct physical interaction (“looking at the calculator”), or a non-manual action verb (“kicking the calculator”). Attentional sentences were found to facilitate only the actions related to the function of the object, whereas action sentences were found to prime also the actions related to grasping it (see also Ambrosini, Scorolli, Borghi, & Costantini, 2012; Borghi & Riggio, 2009). Thus, it seems that the verb associated with the object in the sentence modulates the simulation. It follows from these various studies that when a word denoting a manipulable object is presented in an action context, the associated motor simulation is favoured. We should therefore evidence a greater motor interference when the context highlights action than when it does not. To validate this hypothesis, the present experiment aimed to show that the PI effect on manipulable objects observed by Dutriaux and Gyselinck (2016) will be modulated by an action context. A

PI effect related to the verb was tested with the names of manipulable objects inserted in phrases with action verbs (“To take a cup”) or with attentional verbs (“To see a cup”). The participants had to learn the phrases presented one by one. As in Dutriaux and Gyselinck (2016), they had to put their hands in front of them during the learning phase in the control condition, whereas they had to keep them behind their back in the interfering condition. After a distractive letter-matching task, the participants had to perform a cued recall task. The verbs were presented one by one, and the participants had to recall the object associated with each verb during the learning phase. Previous studies (e.g., Masson et al., 2008) have shown that the simulation of affordance depends on the verb associated with the object, suggesting a sensorimotor simulation of the whole sentence and not of each word individually. The motor simulation related to the object should consequently be less pronounced with attention than with action verbs. Furthermore, if long-term memory is for action, one would expect a worse memory when the context does not favour action. Thus, if a constraining posture that prevents action interferes with motor simulation during encoding, we should expect a PI effect related to the verb, that is, a greater interference effect of the constraining posture on the memory of manipulable objects associated with an action verb than with an observation verb.

Method

Participants

In total, 36 undergraduates studying psychology at Paris Descartes University took part in the experiment for course credits. All participants gave their informed consent to the experimental procedure.

Materials

In total, 40 names of manipulable objects (i.e., tools, for example, “pen,” “hammer”) and 20 verbs were used (see Supplemental Files at the Open Science Framework website: <https://osf.io/kewpu/>). The 40 names of manipulable objects were divided into four lists of 10 objects. Among the verbs, 10 were action verbs (e.g., “to grasp”) and 10 were attentional verbs (e.g., “to observe”), matched in terms of objective frequency ($U=47$, $p=.85$) and word length ($U=29.5$, $p=.12$). Objective frequency means were computed with the database “lexique” (New, Pallier, Ferrand, & Matos, 2001).

Procedure and design

Participants were tested individually in a quiet room with the experimenter present. For each list, participants were exposed to a learning phase, then to a distractive task, and

Figure 1. Means for the percentage of items recalled as a function of verb type and posture. Error bars represent standard errors of the mean (** $p < .01$; *** $p < .001$).

finally to an oral free recall. During the learning phase, half of the names of manipulable objects were randomly associated either with an action verb (e.g., “to grasp a hammer”) or with an attentional verb (e.g., “to observe a hammer”). Each phrase of each list was presented one by one as a whole on a computer screen during 3,500 ms, with an inter-stimulus interval of 1,000 ms. In each list, five of the names of manipulable objects were associated with an action verb, and five were associated with an attentional verb. Given that there are 40 objects for 20 verbs, each verb was used twice, but never in the same list. For each participant, lists were presented randomly, and, within each list, verbal expressions were also presented randomly. Participants were instructed to learn the sentences while adopting different postures. They were said that the verbs will be used as a cue and that they will have to recall the corresponding object. They were warned that they would have to recall the name of the object corresponding to the verb cues. In the control condition, they were instructed to put their hands on the desk in front of them, at rest. They were allowed to move their hands if necessary (e.g., to scratch their head), but not to cross their arms. In the interfering condition, they had to keep their hands behind their back, while holding one of their wrists with the other hand. Each participant was presented with three lists in the control condition and three lists in the interfering condition. The order of the two blocks of three lists was counterbalanced across participants. At the beginning of the 2-min distractive task, participants in the interfering condition had to put their hands back on the desk. Pairs of letters were presented. For each pair, one letter was in upper case, whereas the other was in lower case, and participants had to say orally whether the letters were the same (e.g., “A,” “a”) or different (e.g., “A,” “b”). Finally, still with their hands in front of them, participants had to perform a cued recall task. Each verb was

presented one by one as a cue, and the participants had to recall orally which objects were associated with the verbs during the learning phase.

Results

Figure 1 shows the mean percentages of objects correctly recalled. These percentages were computed by considering that only exact answers (and not synonyms) were correctly recalled. The data were analysed using a 2×2 repeated measure analysis of variance (ANOVA), with verb type and posture as within-subject variables. First, the results showed a main effect of verb type, $F(1, 35) = 21.81$, $p < .001$, $\eta_p^2 = .38$, that is, objects associated with an action verb during the learning phase were better recalled than objects associated with an attentional verb. In line with preceding results (Dutriaux & Gyselinck, 2016), the main effect of posture was nearly significant, $F(1, 35) = 3.9$, $p = .06$, $\eta_p^2 = .10$, with a decrease in the memory of manipulable objects learned with the interfering posture. Crucially, the expected interaction corresponding to the PI effect was found, $F(1, 35) = 9.94$, $p = .003$, $\eta_p^2 = .22$. To assess whether the effect of posture is specific to objects associated with action verbs, two planned comparisons were run, contrasting both postures for each verb type. As predicted, the planned comparisons showed that the interfering posture decreased the memory of objects associated with action verbs, $t(35) = 3.35$, $p = .002$, $\eta_p^2 = .25$, but not of objects associated with attentional verbs, $t(35) = 1.43$, $p = .16$, $\eta_p^2 = .06$.

Discussion

The objective of this experiment was to show that the action context produced by the linguistic context and the posture modulates motor simulation of affordance and, consequently, the memory of words denoting manipulable objects. Participants were presented with lists of phrases that were composed of an action or an attentional verb associated with a manipulable object. Participants had to learn the phrases while adopting a control posture (i.e., their hands free in front of them) or an interfering posture (i.e., hands behind their back). After a distractive task, participants had to recall the objects’ names, with the verb presented as a cue. The results showed first that the recall of the manipulable objects associated with an action verb was better than those associated with an attentional verb. More importantly, the expected PI effect was observed, that is, the postural interference affected the memory of the objects associated with the action verbs, but not the memory of the objects associated with an attentional verb.

This result is first consistent with the idea that memory and motor systems share processing resources. Previous studies have shown that motor simulation of object-related actions is less intense when the object name is presented

with an attentional verb than with an action verb (e.g., Masson et al., 2008). It seems here that the posture with hands behind the back interfered with the motor simulation allowed by the action verbs (and not the attentional verbs), and that this interference decreased the memory of manipulable objects. As suggested by previous work (Matheson et al., 2014), this interference might not be specific to the memory of manipulable objects. A control condition combining verbs and non-manipulable objects would be needed to make sure that this interference is specific to manipulable objects. Given that Dutriaux and Gyselinck (2016) found no effect of posture on single words referring to non-manipulable objects, it is likely that the same would hold with non-manipulable objects associated with verbs, but it would require further investigations. Even though the mechanism behind the postural interference has still to be clarified (see Dutriaux and Gyselinck, 2016), these results are consistent with other studies showing that keeping one's hands behind the back affects motor simulation (e.g., Ambrosini & Costantini, 2017; Sirigu & Duhamel, 2001). Altogether, those elements suggest that motor simulation has indeed a role in memory. This is in line with other studies showing motor interference on manipulable objects (e.g., Lagacé & Guérard, 2015; Myung et al., 2010; Pobric et al., 2010; Witt et al., 2010; Yee et al., 2013), but, as emphasised in the "Introduction" section, contradicts others (e.g., Garcea et al., 2013; Matheson et al., 2014; Zeelenberg & Pecher, 2016). Further investigations are thus needed to support this hypothesis.

Second, this experiment showed that in the conditions that did not favour action—that is, with hands behind the back and with the action verb—the recall of manipulable objects decreased. Even though these results are consistent with the view that memory is for guiding action, this interpretation might be questioned. First, the main effect of verb might be explained by a difference in terms of imageability or concreteness between the two kinds of verbs. It is indeed likely that action phrases are more concrete and imageable than attention sentences, and thus easier to learn, which is a shortcoming for the interpretation of these results. However, it is difficult to explain how concreteness could account for the specific effect of posture on action sentences. One might also argue that it is not possible to say whether the effect of posture arises from the motor or proprioceptive information about the position of the arms, about holding their wrist, or from the visual absence of the hands. That question would be an interesting avenue for future research. However, all of these different explanations involve the fact that the hands are less available for actions, and are thus consistent with the idea that long-term memory and action share processing resources and that memory encodes information in part for guiding action.

This study also has implications for language comprehension. The mental model theory (Johnson-Laird,

1983) claims that language comprehension results from the construction of a situation model. According to this theory, a situation model is an amodal representation that is structurally analogous to the described situation. Thus, a situation model could be seen as an amodal simulation of language. Embodied cognition, however, suggests that situation models are sensorimotor simulations (Barsalou, 1999; Glenberg & Robertson, 1999). Consistent with this idea, some studies have shown that the motor simulation related to the name of a manipulable object depends on whether the context highlights action (e.g., Masson et al., 2008; van Dam et al., 2014). This kind of conceptual flexibility is in line with the idea that language comprehension relies on the sensorimotor simulation of the meaning of the whole sentence, that is, a sensorimotor situation model. However, these motor activations could be the mere consequences of an activation cascade, without any role in comprehension (Mahon & Caramazza, 2008). The present experiment demonstrated a PI effect, that is, a motor interference in the processing of concepts of manipulable objects only when the linguistic context highlighted action. This study is thus the first one, to our knowledge, to show that the modulation of motor simulation has a role in the flexibility of manipulable object concepts, that is, in the construction of situation models. Furthermore, this experiment suggests that the processing of a sentence is modulated by posture, which means that situation models are constructed in the context of our action possibilities. Thus, it can be argued that an embodied situation model does not represent the elements of the described environment necessarily to the same extent, but it represents them in such a way as to guide action.

To sum up, this research newly shows that motor interference, that is, hands behind the back posture, decreases the memory of words denoting manipulable objects when associated with an action verb, but not when associated with an attentional verb. It suggests that motor simulation has a role in long-term memory and language processing. Furthermore, the recalls decreased when the context did not highlight action. Thus, this work shows quite clearly (1) that long-term memory and motor systems share processing resources, and (2) that memory is at least in part for guiding action.

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Open Practices

The data and materials from the present experiment are publicly available at the Open Science Framework website: <https://osf.io/kewpu/>.

Supplementary material

The Open Practices disclosure form is available at journals.sagepub.com/doi/suppl/10.1177/1747021818785096.

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