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Effects of grasp compatibility on long-term memory for objects☆

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ABSTRACT

Previous studies have shown action potentiation during conceptual processing of manipulable objects. In four experiments, we investigated whether these motor actions also play a role in long-term memory. Participants categorized objects that afforded either a power grasp or a precision grasp as natural or artifact by grasping cylinders with either a power grasp or a precision grasp. In all experiments, responses were faster when the affordance of the object was compatible with the type of grasp response. However, subsequent free recall and recognition memory tasks revealed no better memory for object pictures and object names for which the grasp affordance was compatible with the grasp response. The present results therefore do not support the hypothesis that motor actions play a role in long-term memory.

Grounded cognition theories suggest that cognitive processes such as memory and language share processing mechanisms with perception and action (Barsalou, 2008). On this account, conceptual knowledge is not purely represented in abstract symbols but instead is the reactivation of perceptual and motor experiences related to the concept; memory for a concept consists of information from different modalities that is distributed across sensory-motor systems (Barsalou, 1999). In some versions of this account, the main function of concepts is to support our interactions with the environment (Glenberg, 1997; Glenberg, Witt, & Metcalfe, 2013). Thus, motor information should be particularly important for object concepts. When perceiving objects, we purportedly do not just passively perceive them as such but we perceive their manipulable properties (Gibson, 1979). According to Glenberg, these perceived properties are combined with memories of prior actions in order to support actions.

Thus, according to the grounded view, motor actions have a central role in object knowledge. Studies using neuroimaging methods have indeed shown activation of motor or premotor cortical areas when participants process objects (Buccino, Sato, Cattaneo, Rodà, & Riggio, 2009; Chao & Martin, 2000; Creem-Regehr & Lee, 2005; Martin & Chao, 2001; Martin, Wiggs, Ungerleider, & Haxby, 1996). Moreover, results from many studies have indicated that representing objects potentiates actions that are compatible with those objects (Bub & Masson, 2010a; Bub, Masson, & Cree, 2008; Ellis & Tucker, 2000; Masson, Bub, & Breuer, 2011; Tipper, Paul, & Hayes, 2006; Tucker & Ellis, 1998; but see Masson, 2015; Proctor & Miles, 2014). Tucker and Ellis (2004; see also Girardi, Lindemann, & Bekkering, 2010) found compatibility effects when participants categorized objects on photographs as either natural or artifact by using either a power grasp or a precision grasp. Participants responded faster when the response grasp was compatible with the size of the object (and thus the type of grasp that the object afforded, for example a precision grasp for a *needle*). Several findings support the idea that grasp actions are activated as part of the concept. Compatibility effects are found even when the stimuli are words referring to manipulable objects (Bub et al., 2008; Bub & Masson, 2010b; Glover, Rosenbaum, Graham, & Dixon, 2004; Masson, Bub, & Lavelle, 2013; Masson, Bub, & Warren, 2008; Rueschemeyer, van Rooij, Lindemann, Willems, & Bekkering, 2010; Tucker & Ellis, 2004) or when action is not physically possible because the object is outside reaching distance (Tucker & Ellis, 2001; but see Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010; Ferri, Riggio, Gallese, & Costantini, 2011). Bub et al. (2008) showed that grasp compatibility effects are not due to visual similarity between the grasping device and the visual object stimulus, because the compatibility effect was absent when participants had to merely touch the device rather than grasp it. Furthermore, the grasp compatibility effect is found even though size is task-irrelevant (Bub et al., 2008; Tucker & Ellis, 2004). This has been taken to suggest that the grasping action is part of the knowledge that is activated for a concept. Grasp compatibility effects suggest that actions are activated automatically, that is, actions are activated even if the task does not require it, although some studies have shown that activation of actions can be modulated by context (Borghi, Flumini, Natraj, & Wheaton, 2012; Borghi & Riggio, 2015; Jax & Buxbaum, 2010; Kalenine, Shapiro, Flumini, Borghi, & Buxbaum, 2014; Taylor & Zwaan, 2010; Yoon, Humphreys, & Riddoch, 2010). Further support comes from studies that show negative effects of motor-interference on

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processing of concepts (Witt, Kemmerer, Linkenauger, & Culham, 2010; Yee, Chrysikou, Hoffman, & Thompson-Schill, 2013; but see Matheson, White, & McMullen, 2014), and a TMS study by Buccino et al. (2005; but see Pelgrims, Olivier, & Andres, 2011) showing differential modulation of the hand and foot muscle activity when participants read sentences describing actions with hand and foot related objects. These findings suggest that retrieval of knowledge and performing actions share processing mechanisms.

Given that grasping actions appear to constitute a significant part of conceptual memory, the question arises what their role is for other types of memory. In general, conceptual memory and episodic memory are strongly intertwined and may even be indistinguishable (Anderson & Ross, 1980; Dosher, 1984; Glenberg, 1997; Hintzman, 1986; McKoon, Ratcliff, & Dell, 1986). If potential actions are automatically activated when people identify objects, grasping actions could be encoded in memory traces and support short-term and long-term memory. Research on the role of actions in short-term memory for objects has shown mixed results. Support for a role of motor actions was provided by Apel, Cangelosi, Ellis, Goslin, and Fischer (2012) who required participants to keep instructions in working memory about how to move cups across a displayed grid. The handles of those cups could be at either the left side or the right side of the cup. Participants' memory span was worse when the objects' handles were spatially incompatible with the hand used in the instruction actions. Downing-Doucet and Guerard (2014) showed an effect of motor similarity on immediate order memory for pictures of objects. Participants studied lists of pictures of objects that were associated with several types of grasps (i.e., a leaf associated with a precision grip). A short video of a hand performing a grasping movement, either similar or dissimilar to how the object can be grasped, was shown prior to the presentation of each object. Afterwards, participants were immediately presented with the same objects and then had to indicate the order of object presentation. Participants had worse immediate order memory for pictures of objects that shared the same grasping action compared to objects that required different grasps. This interference effect suggests that participants use motor information elicited by the objects to retain the items in memory. In a second experiment, the effect of grasp similarity disappeared when the participants performed a concurrent motor task, suggesting that the effect of grasping similarity was due to involvement of the motor system (see also Guérard & Lagacé, 2014; Lagacé & Guérard, 2015, for similar results). It should be noted, however, that Downing-Doucet and Guérard did focus attention on the object's grasp and the grasp similarity between items by presenting the short videos of a hand making a compatible grasping movement before each object picture. Therefore, these results do not address the question of whether motor actions were spontaneously activated and encoded in memory. Moreover, several studies from our lab (Pecher, 2013; Pecher et al., 2013) obtained evidence that does not support the idea that memory for objects relies on the motor system. In these studies motor-interference tasks did not interfere more with memory for manipulable than nonmanipulable objects. For example, participants were shown several objects and had to keep these in short-term memory. Some objects had hand actions associated to them, for example *hammer* or *scissors*, whereas other objects did not, for example *traffic sign* or *chimney*. If motor actions are automatically recruited for concepts, a concurrent hand movement task should have interfered with activation of motor actions and thus resulted in worse performance for objects that have actions associated to them than for objects that do not have actions associated to them. That we did not find such interaction suggests that the motor system does not contribute to object memory. We also found that there was no memory benefit of performing a compatible grasping action during study compared to an incompatible grasping task (Quak, Pecher, & Zeelenberg, 2014). Thus, some studies showed a role of motor actions for object memory, but others did not.

This mixed state of affairs might be due to the use of short-term memory tasks. In general, research on working memory shows that interference tasks only decrease memory performance if the stimulus and the interfering task share a format (Baddeley, 2003). For example, spatial interference tasks interfere with memory for spatial information but not with memory for (non-spatial) visual information. Moreover, short-term memory might rely mostly on maintenance of the surface properties (orthography, phonology or perceptual characteristics) of the stimulus rather than their meaning (Baddeley, 1966). In a short-term memory task for visually presented objects, motor actions are not task-relevant and the shape and color of the object might just be sufficient to memorize the objects.

In long-term memory, however, conceptual properties of stimuli should be more important. First, as discussed earlier in this paper, perception of manipulable objects seems to activate grasping actions. If these actions are activated automatically, it would be reasonable to assume that they become part of the memory for that object. According to some grounded cognition theories (e.g., Barsalou, 2008; Glenberg, 1997; Glenberg et al., 2013), action information should become part of the object memory, as the action information will serve future interaction with that object. Second, there is an indication for a role of the motor system when participants learn about object functions. For example, Paulus, Lindemann, and Bekkering (2009) showed that participants were slower to retrieve knowledge of the function of recently learned objects when they had performed an interfering hand motor task during learning, compared to a foot motor task or attentional task. Because the functional object knowledge was novel, this finding indicates that the motor system also supports learning when the knowledge is not based on previous motor experiences.

The study by Paulus et al. (2009) thus indicates that the motor system might support memory for object related actions. Very little evidence is available for the role of the motor system in long-term memory for objects. Only two studies that we are aware of have investigated the influence of motor actions on long-term memory for familiar manipulable objects (Guérard, Guerrette, & Rowe, 2015; Van Dam, Rueschemeyer, Bekkering, & Lindemann, 2013). Van Dam et al. found that participants had better recognition memory for studied words denoting objects when the motor task performed during the retention phase (i.e., after initial encoding of all to-be-remembered stimuli) was compatible with the object's affordance (e.g., twisting for *screwdriver*) than when it was incompatible (e.g., pressing for *screwdriver*). Guérard et al., on the other hand, did not obtain evidence that motor actions play a role in long-term memory. They presented pairs of object pictures in action congruent or incongruent positions (e.g., a wine bottle above or below a wine glass). They assumed that seeing the objects in action congruent positions would activate motor actions more strongly than seeing the objects in incongruent positions, and that a concurrent motor-interference task would therefore have a more detrimental effect on memory for congruent than incongruent pairs. Although they did find the predicted interaction in a short-term memory task, no such effect was obtained in a long-term memory task. Given the large number of studies that have investigated the role of the motor system for conceptual memory it is remarkable that there are so few studies that have investigated its role for long-term memory. In addition, the conflicting results both in short-term and long-term memory studies raise the question how important the motor system is for memory. The current study thus aimed to test whether activated motor actions support long-term memory of objects.

We adopted the stimulus-response grasp compatibility paradigm (Tucker & Ellis, 2004) and extended it to include a free recall memory test. During study, participants categorized photographs of objects that afforded different grasps as natural or artifact, just as was done by Tucker and Ellis (2004). As response devices we used a thick graspable cylinder and a thin graspable cylinder in order to manipulate the compatibility between the object's grasp (power or precision) and the type of grasp response (power or precision). One potentially important difference between Van Dam et al. (2013) and Guérard et al. (2015) was that in Van Dam et al.'s study, participants performed actual