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The role of motor affordances in immediate and long-term retention of objects☆

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A B S T R A C T

In line with the embodied cognition perspective stating that cognitive processing results from the activation of the sensorimotor systems involved in perception and action (e.g., Glenberg, 1997), recent studies provided evidence that motor affordances played a role in serial memory for objects (e.g., see Downing-Doucet & Guérard, 2014). In the present study, we extended this line of research by investigating whether objects' motor affordances played a role in item memory, in immediate and long-term retention. Participants had to retain pairs of objects that were positioned in a way that was congruent for action or not. The results showed that motor suppression disrupted the retention of congruent pairs, but not that of incongruent pairs when short lists of six objects had to be retained over a short period of time (Experiment 1). However, when participants had to retain lists of 60 pairs, motor suppression had no effect on retention (Experiment 2). These results suggest that the motor system was recruited for the immediate retention of objects, but not for their long-term retention.

During the last decades, researchers have become increasingly interested in the role of objects' motor affordances – the actions that can be performed in relation to an object – in cognition. This body of research is mostly inspired by the embodied cognition perspective stating that cognitive processing relies solely on the sensory and motor systems used to interact with the world around us (e.g., Barsalou, 1999; Glenberg, 1997; Versace, Labeye, Badard, & Rose, 2009). For instance, recent evidence suggested that the activation of the actions associated to an object plays a role in object recognition (e.g., see Helbig, Steinwender, Graf, & Kiefer, 2010). Other studies point to the role of the motor system in serial memory for objects by showing that manipulating the objects' motor affordances influence their retention (e.g., see Downing-Doucet & Guérard, 2014; Guérard & Lagacé, 2014). These studies however, used serial recall paradigms where participants were required to retain short sequences of objects in the same order they were presented. Thus, it is unclear from these results whether motor affordances are used to retain the objects' themselves or their serial order, and whether the same motor processes operate during immediate and long-term retention. The objective of the present study is therefore to examine whether motor affordances play a role during item retention in immediate and long-term memory for objects.

1. Immediate retention and the motor system

Most models developed to account for immediate memory suggested that retention relied on specialised memory processes such as the existence of a store for phonological representations and a mechanism for keeping those representations active for immediate use (e.g., Baddeley & Hitch, 1974; Burgess & Hitch, 1999; Page & Norris, 1998). Recently, more parsimonious accounts have been developed that question the existence of specialised memory stores or processes (e.g., see Barsalou, 1999; Glenberg, 1997; Versace et al., 2009). For instance, according to theories of embodied cognition, memory would rely on the sensory and motor systems that are recruited to interact with the objects in the environment. More precisely, some authors suggested that immediate retention recruited the motor systems – or skills – most appropriate to embody the type of information to retain (e.g., Glenberg, 1997; Jones, Hughes, & Macken, 2006; Kolers & Roediger, 1984).

In the verbal domain, a number of studies suggested that immediate serial retention relied on the language production architecture (e.g., see Acheson & MacDonald, 2009; Woodward, Macken, & Jones, 2008). For instance, some authors showed striking similarities between errors occurring in verbal serial recall and speech errors, suggesting a common locus (e.g., Ellis, 1980; Page, Madge, Cumming, & Norris, 2007). Similarly, in the spatial domain, eye movements appear as a privileged medium for rehearsing sequences of dot locations in a particular order (e.g., see Theeuwes, Belopolsky, & Olivers, 2009; Tremblay, Saint Aubin, & Jalbert, 2006). For instance, some studies showed that interfering with eye movements through the use of a suppression task where participants were asked to move their eyes to irrelevant locations

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interfered with spatial memory (Guérard, Tremblay, & Saint-Aubin, 2009; see also Guérard & Tremblay, 2011). Therefore, these studies provide support for the idea that the motor system is recruited for retention, with verbal retention relying on the language production architecture and spatial retention relying on the oculomotor system. More specifically, Jones et al. (2006) suggested that the motor system was particularly useful to retain the transitions between the successive items. For instance, in the verbal domain, articulating the list of items would allow organising the list by creating a chain of articulatory gestures (see also Woodward et al., 2008).

In the domain of object memory, recent evidence also pointed to the idea that objects are retained via the motor system that is recruited to physically interact with them. Evidence comes from studies showing that objects' motor affordances influenced retention (e.g., see Downing-Doucet & Guérard, 2014; Guérard & Lagacé, 2014). For instance, Guérard and Lagacé showed that when the manipulability level of an object was isolated in a list of objects to retain for serial recall, performance improved for the isolated item. This advantage was abolished when participants were asked to perform motor suppression during the task. In another study, Downing-Doucet and Guérard manipulated the similarity between the actions associated to the objects to retain in order memory. They showed that lists of objects associated to similar actions were more difficult to retain than lists of objects associated to dissimilar actions.

The finding that motor affordances influenced object retention suggests that the motor system used to physically interact with these objects is recruited for their immediate retention. In line with previous studies, Downing-Doucet and Guérard (2014) suggested that the motor system was recruited in order to seriate information by creating a chain of motor actions associated to the objects to retain. However, one question that has not been investigated in these studies is whether or not the motor system is also recruited for retaining the objects individually, that is, for item retention. For instance, several studies showed that enacting action phrases such as "lift the pen" is beneficial for retaining the sentences in isolation, but is detrimental for retaining their serial order (e.g., Engelkamp & Dehn, 2000; Olofsson, 1996). Other studies showed that retaining a single manipulable object in memory activated the brain areas involved in body–object interactions (Mecklinger, Gruenewald, Besson, Magnié, & Cramon, 2002; Mecklinger, Gruenewald, Weiskopf, & Doeller, 2004). These results therefore point to the idea that the motor system might also be recruited for item retention.

2. The distinction between immediate and long-term memory

The distinction between immediate and long-term memory systems is a central idea of a long tradition of theories and models of memory (e.g., Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Hulme, Maughan, & Brown, 1991). As a consequence, most researchers refer to the processes that allow retaining information for a short period of time using the terms "short-term memory" or "working memory", which imply that immediate retention relies on processes that are distinct from those recruited for long-term memory. However, a number of researchers have questioned this distinction and suggested that the same memory processes were called upon over different timescales (e.g., Brown, Neath, & Chater, 2007; Brown, Preece, & Hulme, 2000; see also Cowan, 1993).

In line with this idea, theories of embodied cognition suggested that immediate retention relied on the same perceptual and motor systems that are recruited during retrieval from long-term memory (e.g., see Barsalou, 1999; Glenberg, 1997; Versace et al., 2009). For example, Glenberg (1997) suggested that representations are embodied and grounded within the sensory and motor systems. When an object is presented (i.e., a cup), activation of the possible patterns of actions based on information from the environment (i.e., shaping the hand and moving the arm to seize the cup depending on its size, location, orientation, etc.) would be meshed with the patterns of actions based on previous experience (i.e., taking the cup to the mouth). The resulting pattern of activation is considered a *conceptualisation* that allows interaction with the object (i.e., drinking). According to Glenberg, immediate memory is no different than long-term memory: immediate memory is considered an illusion resulting from the change from one conceptualisation to a new conceptualisation (see also Kolers & Roediger, 1984), what Glenberg termed a *trajectory*. Despite the assumption of the embodied cognition perspective that immediate retention relies on the same processes as long-term retrieval, no studies have investigated whether the same motor processes that are recruited during object immediate retention are also involved during their long-term retention.

3. The present study

The objective of the present study was to examine the role of the motor system in item retention, in immediate and long-term memory for objects. Participants were required to retain pairs of objects for a later recognition test. In order to examine the role of the motor system, we manipulated the relationship between the objects of each pair (e.g., see Roberts & Humphreys, 2010). In the congruent condition, the objects were presented so that their disposition evoked an action. For instance, a jug was combined with a glass in a position that would allow liquid to be poured into the glass. In the incongruent condition, the two same objects were presented in the same orientation, but their spatial location was swapped so that liquid could no longer be poured into the glass (see Fig. 1). Such pairs have been used in studies on object identification (e.g., see Borghi, Flumini, Natraj, & Wheaton, 2012; Roberts & Humphreys, 2010, 2011; Yoon, Humphreys, & Riddoch, 2010). For instance, Roberts and Humphreys (2011) showed that pairs that were positioned in order to evoke an action were recognised faster than pairs that did not evoke an action. They suggested that such facilitation was due to the perceptual grouping induced by their motor relationship, as well as by the activation of an action by the active object.

In addition to manipulating the congruency between the objects of a pair, we manipulated motor suppression, which consisted of asking participants to execute a complex movement pattern with their hands during the encoding of the pairs (e.g., see Pecher, 2013). Such task has been used in a number of studies in order to interfere with the activation of the actions associated with the objects (e.g., see Guérard & Lagacé, 2014; Pecher, 2013). For instance, Guérard and Lagacé (2014) showed that motor suppression abolished the isolation effect produced by isolating the motor characteristics of one object from a list, but not when isolating its semantic category. This result suggests that motor suppression interferes with the motor processes involved in retention. In the suppression group, participants were therefore required to perform motor suppression during the encoding of the objects while in the control group, they only had to memorise the objects. In contrast to other paradigms such as the self-performed task showing that performance improves when participants are asked to pantomime the action evoked by the items to retain (e.g., see Engelkamp & Zimmer, 1989), participants in the control group were not required to perform any action. Such a control condition was used in order to manipulate the actions activated by the visual presentation of the objects rather than by performing them and have been used in previous studies on object memory (e.g., Downing-Doucet & Guérard, 2014; Lagacé & Guérard, 2015; Mecklinger, Gruenewald, Besson, et al., 2002; Mecklinger, Gruenewald, Weiskopf, et al., 2004; Pecher, 2013; Pecher et al., 2013).

In Experiment 1, participants had to memorise six pairs of objects in every trial. In Experiment 2, participants were required to memorise a set of 60 pairs before doing the recognition test. In each experiment, we assessed the effect of motor suppression on recognition performance. In order to further investigate the motor processes that are called upon during the task, we also measured recognition accuracy for the active and passive objects of the pairs.