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Visual objects speak louder than words: Motor planning and weight in tool use and object transport

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ABSTRACT

For theories of embodied cognition, reading a word activates sensorimotor representations in a similar manner to seeing the physical object the word represents. Thus, reading words representing objects of different sizes interfere with motor planning, inducing changes in grip aperture. An outstanding issue is whether word reading can also evoke sensorimotor information about the weight of objects. This issue was addressed in two experiments wherein participants have first to read the name of an object (Experiment 1)/observe the object (Experiment 2) and then to transport versus use bottles of water. The objects presented as primes were either lighter or heavier than the bottles to be grasped. Results indicated that the main parameters of motor planning recorded (initiation times and finger contact points) were not affected by the presentation of words as primes (Experiment 1). By contrast, the presentation of visual objects as primes induced significant changes in these parameters (Experiment 2). Participants changed their way of grasping the bottles, particularly in the use condition. Taken together, these results suggest that the activation of concepts does not automatically evoke sensorimotor representations about the weight of objects, but visual objects do.

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1. Introduction

Theories of embodied cognition posit that cognitive representations are grounded in the brain's motor and sensory systems (Barsalou, 2008; Semin & Smith, 2008). In this view, reading a word activates sensorimotor representations in a similar manner to seeing the physical object the word represents (Borghi, 2004; Glenberg, 1997; Pecher & Zwaan, 2005). Evidence with response time studies (Borghi & Riggio, 2009; Buccino et al., 2005), kinematic measures (Glover & Dixon, 2002; Nazir et al., 2008) or brain-imaging studies (Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Kellenbach, Brett, & Patterson, 2003; Pulvermüller, 2003) supports this view by showing that words evoke perceptual and motor information regarding their referents. Evidence also indicates that word reading can interfere with motor planning. For instance, when participants are asked to first read a word and then grasp a wooden block, reading a word representing a large object (e.g., apple) leads to a larger grip aperture than reading a word representing a small object (e.g., grape; see Glover, Rosenbaum, Graham, & Dixon, 2004). Interference effects, however, arise only in the early portions of the grasping movements, suggesting that they only concern the planning of action but not their on-line control. An outstanding issue is whether, as predicted by theories of embodied cognition, word reading can be sufficient to evoke sensorimotor information about the weight of objects and, as a result, can interfere with motor planning. No study so far has explored this issue. The present study is designed to do so.

The ability to evaluate the weight of objects is central to grasp and lift objects to manipulate them in a purposeful way (i.e., object transport or tool use). A significant body of literature has indicated that when people perform repeated lifts of a single object, they rapidly learn to link the identity of the object with the forces necessary for its manipulation (Gordon, Westling, Cole, & Johansson, 1993; Gordon, Forssberg, & Iwasaki, 1994; Johansson & Cole, 1992; Johansson & Westling, 1984). Inappropriate grip forces are generated only at the first lift and a more accurate force scaling is observed by the second lift when the weight is kept constant (see Nowak, Koupan, & Hermsdörfer, 2007; see also Nowak, Glasauer, & Hermsdörfer, 2013). In other words, in case known objects are grasped and lifted, people plan grip and lift forces based on predictions from prior experience with the object and its manipulation. People can also employ reactive strategies, by modifying their grip force in response to sensory feedback, as for example when the object lifted is heavier than expected (Brouwer, Georgiou, Glover, & Castiello, 2006; Jenmalm, Schmitz, Forssberg, & Ehrsson, 2006; see also Nowak et al., 2013).

Besides adapting the grip and lift forces, people can place their fingers on the object to be grasped at different positions in order to increase motor control during manipulation. For instance, Sartori, Straulino, and Castiello (2011) asked participants to grasp and lift a completely full versus a half-full bottle of water either to move it from

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one location to another (object transport) or to pour some of its contents into a glass (tool use). They found that movement time was shorter when the bottle was half-full compared to completely full as well as when the end-goal of the action was moving rather than pouring (for somewhat similar results, see Jax & Buxbaum, 2010; Osiurak, Roche, Ramone, & Chainay, 2013). More interestingly, they observed that the fingers were placed lower for the half-full rather than the completely full bottle. In other words, people not only modify their grip and lift forces, but also adapt the placement of their fingers on the object in function of the weight of object in order to increase motor control during manipulation. Evidence indicates that finger/hand placement on an object to be grasped is necessarily anticipated and planned and not adjusted during the reaching phase (e.g., Cohen & Rosenbaum, 2004).

To sum up, theories of embodied cognition assume that words might spontaneously evoke perceptual and motor information regarding their referents. Consistent with this, reading a word representing a large versus a small object has been shown to interfere with motor planning, leading to changes in grip aperture in the early portions of the movement (Glover et al., 2004). The issue here is whether reading a word is also sufficient to evoke sensorimotor information about the weight of the corresponding object. To explore it, we combined the paradigms of Glover et al. (2004) and Sartori et al. (2011). Participants had to first read words representing a heavy versus a light object and then to grasp a bottle either to transport or to use it as a tool. As discussed, finger placement is a good indicator of motor planning in response to the weight of objects. The rationale was as follows. If word reading is sufficient to evoke sensorimotor information about the weight of the corresponding objects, then it should interfere with motor planning and, more particularly, with finger placement. For instance, participants should place their fingers lower after reading the word of a light object, and higher for a heavy object. This prediction was examined in Experiment 1 with words as primes. To examine the specificity of our findings with words, we also conducted a second experiment (i.e., Experiment 2) with real objects as primes.

2. Method

2.1. Participants

Forty undergraduate students from the University of Lyon took part in Experiment 1 ($n = 20$; 12 women; $M_{age} = 20.96$, $SD_{age} = 2.49$) and Experiment 2 ($n = 20$; 15 women; $M_{age} = 21.08$, $SD_{age} = 1.85$). All participants were right-handed (Edinburgh score > 70) and had normal or corrected-to-normal visual acuity. Informed consent was obtained from the participants. The study was conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki.

2.2. Materials

A schematic representation of the apparatus is illustrated in Fig. 1. Participants were seated at a table. A start button was situated on the table at a comfortable distance from the participant (30 cm). Objects were placed on a support at 60 cm from the participant so that the participant could easily grasp them. The objects to be grasped were ordinary cylindrical bottles (70 mm diameter; 230 mm height). Each bottle weighted 290 g when one-third full of water and 510 g when two-thirds full of water. Primes corresponded to an object lighter (i.e., a tennis ball; 6 cm diameter; 70 g) and an object heavier (i.e., a pétanque ball; 6.5 diameter; 730 g) than the objects to be grasped. In total, there was an increment of 220 g from the lightest to the heaviest object (Tennis ball, 70 g; one-third-full bottle, 290 g; two-thirds-full bottle, 510 g; pétanque ball, 730 g). In Experiment 1, all primes were written in small letters (font: Times New Roman; size: 52; color: black) and presented on a single, white card (14.8 cm × 21 cm) in a landscape orientation and at about 60 cm from the participant. In Experiment 2, the real objects were presented. A can was used for no-go trials. Finally, in the use condition, an ordinary glass, located at about 30 cm to the right of the position of the bottles, was used. In the transport condition, there was no glass, but the bottle had to be moved to the same location. A high-level camera was positioned to record finger contact points (see Fig. 1).

2.3. Procedure

In both Experiment 1 and Experiment 2, each participant performed two experimental conditions using only the right hand. In the transport condition, instructions were to grasp the bottle and to move it to the target position. In the use condition, participants were asked to grasp the bottle and to pour some of its contents into the glass. Half of the participants performed one block of 62 transport trials followed by a brief instruction break and then one block of 62 use trials. The remaining participants completed the blocks in the reserve order. Each block included 8 training trials, 6 no-go trials and 48 test trials (2 type of primes × 2 types of bottles × 12 trials). The can on no-go trial was introduced to encourage object identification before movement initiation (Jax & Buxbaum, 2010; Osiurak et al., 2013). No-go and test trials were presented in a different random order in each block.

A schematic representation of the sequence of events for a trial is illustrated in Fig. 1. Trials began with the participant holding down the

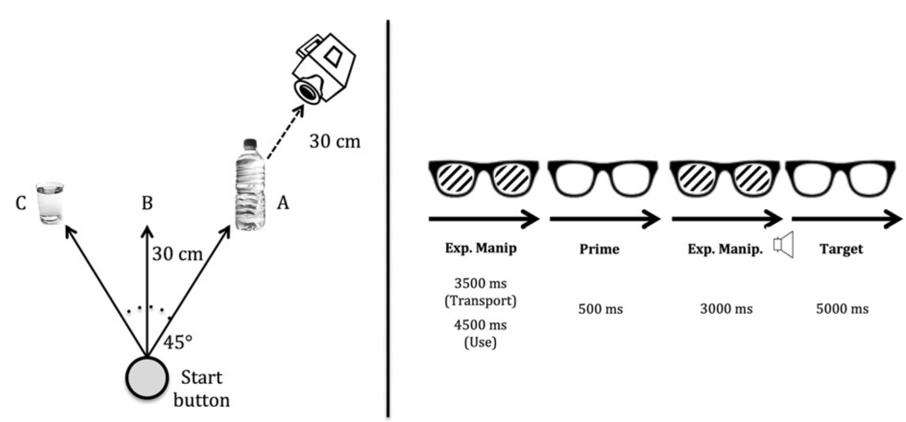

Fig. 1. Experimental setup and sequence of events for a trial. The left panel represents the schematic representation of the apparatus used in both experiments of the present study. The position A is the initial position of the bottle. The position B corresponds to the position of the prime (words written on a card for Experiment 1; visual objects for Experiment 2). The position C is the target position for the transport condition and the position of the glass for the use condition. Here, the use condition is illustrated because no glass was presented in the transport condition. The right panel shows the sequence of events for a trial. Exp. Manip. corresponds to the experimental manipulation performed by the experimenter between prime and target events. Further explanation is given in the text.

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