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Switching between lift and use grasp actions

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ABSTRACT

Switching between competing grasp postures incurs costs on speeded performance. We examined switch costs between lift versus use actions under task conditions that required subjects to identify familiar objects. There were no asymmetrical interference effects, though reliable costs occurred when the same object required a different action on consecutive trials. In addition, lift actions were faster to objects targeted for a prospective use action than objects irrelevant to this intended goal. The benefit of a lift-then-use action sequence was not merely due to the production of two different actions in short order on the same object; use actions to an object marked for the distal goal of a lift action were not faster than use actions applied to another object. We propose that the intention to use an object facilitates the prior action of lifting it because the motor sequence *lift-then-use* is habitually conscripted to enact the proper function of an object.

1. Introduction

Grasp actions vary depending on whether we wish to use or lift an object. To use an object according to its proper function, manual actions are often directed at structural features that are not the most salient (e.g., depressing the keys of a cellphone to make a call). These actions are guided by stored knowledge, also referred to as *manipulation knowledge*, of how we typically use an object (Osiurak & Badets, 2016). The grasp applied for lifting instead of using an object can be generated directly from the object's global shape. At least in principle, lift actions can be accomplished without prior knowledge of actions linked to an object’s identity, and so should be generated more rapidly than use actions.

Under certain task conditions, lift actions are indeed produced faster than use actions on the same objects (Jax & Buxbaum, 2010; Osiurak & Badets, 2016). For example, Jax and Buxbaum presented familiar objects one at a time to subjects whose vision was initially occluded by liquid crystal display goggles. Shortly after a warning tone, the goggles cleared to reveal a single object on a platform. Depending on the instructions, a given block of trials required the subject to apply either a lift or a use grasp action to the revealed object. Irrespective of task order, lift actions were generated more rapidly than use actions (Jax & Buxbaum, 2010; Osiurak, Roche, Ramone, & Chainay, 2013). Furthermore, for objects that required different use and lift hand postures (e.g., a power grasp for lifting a pocket calculator and a closed hand with an extended index finger for using it), production of use actions interfered with the subsequent production of lift actions to the same objects.

Two possible explanations have been proposed for the *use-on-lift* interference effect reported by Jax and Buxbaum (2010). The representation of a use action might remain active long after it has been generated to a particular object. A subsequent lift action would then be delayed if the same object continued to evoke the prior (and competing) use action. Alternatively, repeated production of use actions may induce a task set that entails an overall bias towards using rather than lifting objects. If the task set persists, the motor system will trigger a use action that interferes with the production of a lift action.

In what follows, we re-consider the nature of the motor representations governing use and lift actions under different task conditions. Note that the goal of a use action is typically defined in abstract terms. The action occurs in order to carry out the predetermined function of a tool or utensil, an object property that is necessarily dependent on stored knowledge. By contrast, the intention behind a lift action is usually defined more concretely. We produce these actions “… simply to grasp and move the object from one location to another” (Osiurak & Badets, 2016; p. 538). In fact, though, a variety of distal goals can be satisfied by the lifting of an object. We may reach for and lift an object to rapidly snatch it away from a child, for example, if we perceive the object to be dangerous. We can lift and hand the object to someone else; we can lift and transport the object to a new location. Finally, we may grasp and move an object into our peri-personal space because we intend to use it.

There is good evidence that not all these ways of lifting an object are performed without access to stored knowledge. Osiurak et al. (2013) have reported that lift actions are in fact generated more slowly than

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use actions when the goal of lifting is to hand the object to another person. These authors suggested that a "lift-to-give" action is determined not only by perceptual information like the object's position and size, but also requires access to long-term knowledge of an object's weight and other non-visual attributes.

Other results confirm that stored motor representations are accessed for grasp actions directed at lifting, as well as using, an object. Gentilucci (2002) has shown that knowledge of how we typically interact with objects has an influence on the kinematics of a grasp action. Herbort and Butz (2011) found that habitual actions determine the grasp chosen to rotate an object, overriding the posture more directly afforded by the intended goal of the movement. We have recently established that depicted objects, even when rotated from their upright orientation, can rapidly trigger constituents of grasp actions based on their canonical (upright) description if task demands draw attention to this stored representation (Bub, Masson, & Kumar, 2018; Chua, Bub, Masson, & Gauthier, in press).

Recent methodological developments in robotics also place emphasis on the role of prior knowledge in the formation of lift actions. As noted by Bohg, Morales, Asfour, and Kragic (2014), many computational approaches rely on a data base of object models associated with a set of stable grasps determined by prior experience. Once an object has been recognized, its position or pose is estimated and a suitable grasp retrieved from an "experience database". For novel objects, it is often possible to generate grasp postures from stored knowledge of familiar objects they resemble. It is only when task demands minimize any dependence on prior experience that candidate grasps are generated via direct consultation of structural data.

To summarize, the role of stored knowledge in the production of lift versus use actions is of considerable interest. Switching between actions types carried out on objects that appear suddenly after occlusion yields evidence consistent with the view that lift actions are produced by a fast visuomotor route that does not rely on stored motor representations. We wish to further evaluate switch costs incurred when producing use versus lift actions to a set of familiar objects that remain continuously in view. Assume these objects are all clearly visible and placed close together, and that a grasp action is produced to one object (e.g., *use the cellphone*), followed by another action carried out on the same (*lift the cellphone*) or a different object (*lift the pencil*), and so on. Because each of the possible targets remains constantly in view, the task requires the programming of various grasp actions to objects that have already been identified, the situation that normally applies to the production of use or lift actions on objects in peri-personal space. The question of interest is the following: what switch costs, if any, occur under these conditions, and what light do they shed on the nature of lift and use actions?

2. Experiment 1

In Experiment 1, subjects were cued on each trial to initiate a lift or use grasp action to an object by the image of a hand grasping that object with the appropriate grip (see Fig. 1). Subjects made their response by reaching and grasping one of three response elements continuously available in front of them, as shown in Fig. 1. A continuous sequence of cued reach-and-grasp responses was executed with the critical manipulation being the relationship between the action performed on the current trial and the action performed on the previous trial. These trial-to-trial transitions allowed for repetition of the same action on consecutive trials and for three types of action switch: different action (different action applied to the same object on two consecutive trials), different object (the object changed across two trials, but the same action type was applied), and both action and object were different across the two trials.

Response times were used to measure the cost of switching one or both components of the object-action configuration across two consecutive trials. The switch costs observed in Experiment 1 should reflect the influence of a completed task on the performance of a newly established task and serve as a baseline against which to compare the switch costs in Experiment 2, where a specified action is generated in response to an imperative sentence.

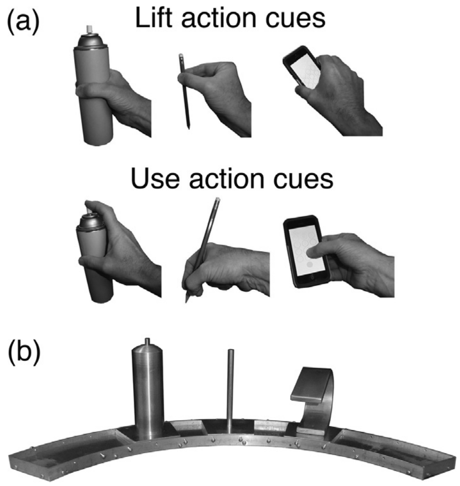

Fig. 1. Action cues (a) and response apparatus (b) used in Experiment 1.

2.1. Method

2.1.1. Subjects

Thirty-two English-speaking students (25 female, age range 18–26 years, median = 20 years) were recruited from undergraduate psychology classes at the University of Victoria. They were given extra credit in their course as an incentive to participate in the experiment. The target sample size ($n = 32$) was commensurate with the goal to detect a small effect size ($d = 0.2$) in a related-samples pairwise comparison assuming a correlation between related samples of between 0.90 and 0.95, power of 0.80, and type I error rate of 0.05. Past research using reach-and-grasp actions in our laboratory have yielded correlations between conditions in that general range. Sample-size estimates were computed using G∗Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009).

2.1.2. Materials

Unique use and lift grasps (one grasp of each type for each object) were identified for three specific objects: cellphone, pencil, and spray can. Digital grayscale photographs were made with each of the three objects posed with a male human right hand demonstrating each of the associated actions (see Fig. 1). A second version of these images was created by making a mirror reversal of each original for use with left-handed subjects. These images were used as cues to indicate to subjects which action to perform on a given trial.

2.1.3. Procedure

Subjects were tested individually in a quiet room. The images serving as action cues were presented on a monitor positioned about 50 cm from the subject. Stimulus presentation and data collection were controlled by an iMac computer. Image presentation was initiated by having the subject use the index finger of their dominant hand to press a button on a button box that was placed on the table in front of the subject. A response was initiated by lifting the response hand from the button, providing a measure of liftoff time. The subject then reached and grasped an element mounted on a response apparatus was positioned between the button box and the computer monitor (see Fig. 1). Three elements were mounted on the apparatus, each to be used for the use and lift actions associated with one of the three objects. Positioning of the elements on the base of the apparatus was counterbalanced across subjects. A weak electrical current was passed through the apparatus which was connected to the computer that controlled the