Consciousness and Cognition 20 (2011) 1304–1314

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Learning to use novel objects: A training study on the acquisition of novel action representations

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ARTICLE INFO

Article history:
Received 6 November 2009

Keywords:
Novel objects
End location
Grip
Action representations
Action observation

ABSTRACT

Many studies have suggested that the motor system is organized in a hierarchical fashion, around the prototypical end location associated with using objects. However, most studies supporting the hierarchical view have used well-known actions and objects that are highly over-learned. Accordingly, at present it is unclear if the hierarchical principle applies to learning the use of novel objects as well. In the present study we found that when learning to use a novel object subjects acquired an action representation of the end location associated with using the object, as evidenced by slower responses in an action observation task, when the object was presented at an incorrect end location. By showing the importance of knowledge about end locations when learning to use a novel object, the present study suggests that end locations are a fundamental organizing feature of the human motor system.

1. Introduction

Imagine yourself wandering around in a museum of modern art, in which all types of different colored objects are placed at tables. A sign on the wall encourages you to grasp the objects to find out what happens. When you grasp the first object, you notice that a tiny melody comes out of the object and you move the object closer to your ear. Your movement towards the next object elicits a breeze of rose smell and you move the object towards your nose to find out whether it is the object that produces the odor. As the example nicely illustrates, the end location to which objects are directed plays an important role in understanding what the object can be used for. For example, we put headphones in our ears to listen to music or we grasp a comb to straighten our hair before dinner.

Developmental studies suggest that the ability to grasp and to play with objects precedes infant's knowledge about what an object can be used for (Barrett, Davis, & Needham, 2007). Within the first year of life infants gradually learn how to grasp and manipulate objects according to their physical properties (Bourgeois, Khawar, Neal, & Lockman, 2005), but it is only during the second year of life that children develop the ability to effectively grasp and use objects in a meaningful fashion (e.g. grasping a spoon to eat; McCarty, Clifton, & Collard, 1999). For example, when presented with a spoon with the handle oriented to the left or the right, 9-month old infants always grasped the spoon with their dominant hand, irrespective of the object's orientation, ending up with an odd grip when approaching the mouth. In contrast, older infants anticipated the desired end location (i.e. bringing the spoon to the mouth) and adjusted their manner of grasping the spoon depending on the object's orientation.

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doi:10.1016/j.concog.2011.03.014

The finding that older infants learn to adjust their manner of grasping according to the desired end location is an instance of the more general principle that the way in which people approach and grasp objects is largely determined by their consecutive use. Studies in the domain of motor control show for instance that during grasping movements people automatically select the handgrip in a way that they will end the movement in a comfortable end-position, which is known as the end-state comfort effect (Rosenbaum, Vaughan, Barnes, & Jorgensen, 1992). These findings are in line with the view that our motor system is organized in a hierarchical fashion and that the specific grip that is used for grasping an object is selected in accordance with a specific end location (Grafton & Hamilton, 2007; Majdandzic et al., 2007; van Schie & Bekkering, 2007). In support of this view, it has been found that neurons in the inferior parietal lobe of the monkey respond differently if the same grasping action is part of an action sequence directed towards the mouth (e.g. grasping to eat) or towards the table (e.g. grasping to place), suggesting that different movement elements are linked to their final end location (Fogassi et al., 2005). In addition, it has been found that the processing of goal- and grip-related information during action planning calls upon different brain networks (Majdandzic et al., 2007; van Schie & Bekkering, 2007). Furthermore, recent studies suggest that conceptual knowledge about objects may be organized in a hierarchical fashion as well around the prototypical end location associated with objects (Lindemann, Stenneken, van Schie, & Bekkering, 2006; van Elk, van Schie, & Bekkering, 2008b). That is, because we have a lot of experience bringing objects to specific end locations (e.g. we typically move a cup towards our mouth in order to drink) strong associations exist between an object and the object's associated end location (e.g. cup-mouth).

However, most studies discussed thus far involved actions and objects that were highly familiar and over-learned. Accordingly, at present it is unclear if the dominance of end locations over grips in our interaction with objects reflects a general feature of the human motor system, or is limited to well-known or familiar actions. The aim of the present study was to investigate if the dominance of end locations over grips applies to the acquisition of novel action representations concerning the object's use as well. To investigate this question we employed an object training paradigm. Subjects first trained to use novel objects in a specific fashion. In the first experiment subjects learned to use objects that elicited a specific action effect (i.e. producing a sound or odor when brought towards the ear or nose) and in the second experiment subjects trained with objects without an action effect. The rationale for using objects that elicited an action effect in the first experiment was to mimic naturalistic object use as close as possible. That is, in daily life most of our actions do not consist of the arbitrary movement of objects towards end locations, but the movements have a specific function (e.g. grasping a headphone to bring it towards the ear serves the function of hearing). To replicate the findings from the first experiment and to examine the importance of object function for learning end locations, in a second experiment subjects practiced with objects that did not elicit an action effect.

After subjects trained with the novel objects, an object recognition task was administered, in which subjects were first presented with a photograph of a trained or untrained object, which was followed by an action snapshot. The picture of the single object served as an implicit cue for the retrieval of action information associated with that object (e.g. the object is brought towards the ear). Previous studies have indicated that action information about objects is automatically activated when objects are perceived (e.g. Bub, Masson, & Cree, 2008) and that an important aspect of this knowledge consists of the object's prototypical end locations (van Elk, van Schie, & Bekkering, 2009).

The object picture was followed by an action snapshot, in which subjects observed an actor performing an action with the object that was correct or incorrect with respect to how subjects were trained to use the objects. Subjects were instructed to decide if the objects that were presented in the two subsequent pictures (single object and the action snapshot) involved the same object or different objects (two-choice response task). A comparable action observation paradigm has been used successfully to assess the functional organization of conceptual knowledge about well-known objects (van Elk, van Schie, & Bekkering, 2008a). By manipulating the correctness of the action context in which an object was presented, a stronger interference of end location–violations (e.g. cup presented near ear) than of grip-violations (e.g. cup presented with odd grip) was found, suggesting that conceptual knowledge for understanding other's actions is organized primarily around end locations. In a similar fashion, in the present study the end location and the grip that the actor applied to the objects were independently manipulated. Although the action–object relation was only implicit and irrelevant to the subjects' task (same/different decision), a facilitation in object identification was expected if the observed action was appropriate for the object. Trials with incorrect or incompatible actions, on the other hand, were expected to delay object identification, and to result in slower reaction times. As a consequence, any effect of the action correctness on reaction times could be regarded as an implicit effect of activated action representations on the processing of observed actions.

2. Experiment 1

2.1. Methods

In the first experiment subjects performed goal directed actions with objects that elicited a sound-effect or an odor-effect when brought towards the ear or nose respectively. Accordingly, the objects had a clearly defined function that was directly related to the specific way in which the object was grasped and moved towards the face. After training, subjects conducted an object recognition task, deciding whether two subsequent pictures (single object and the action snapshot) represented