



Review

Action semantics: A unifying conceptual framework for the selective use of multimodal and modality-specific object knowledge

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Abstract

Our capacity to use tools and objects is often considered one of the hallmarks of the human species. Many objects greatly extend our bodily capabilities to act in the physical world, such as when using a hammer or a saw. In addition, humans have the remarkable capability to use objects in a flexible fashion and to combine multiple objects in complex actions. We prepare coffee, cook dinner and drive our car. In this review we propose that humans have developed declarative and procedural knowledge, i.e. action semantics that enables us to use objects in a meaningful way. A state-of-the-art review of research on object use is provided, involving behavioral, developmental, neuropsychological and neuroimaging studies. We show that research in each of these domains is characterized by similar discussions regarding (1) the role of object affordances, (2) the relation between goals and means in object use and (3) the functional and neural organization of action semantics. We propose a novel conceptual framework of action semantics to address these issues and to integrate the previous findings. We argue that action semantics entails both multimodal object representations and modality-specific sub-systems, involving manipulation knowledge, functional knowledge and representations of the sensory and proprioceptive consequences of object use. Furthermore, we argue that action semantics are hierarchically organized and selectively activated and used depending on the action intention of the actor and the current task context. Our framework presents an integrative account of multiple findings and perspectives on object use that may guide future studies in this interdisciplinary domain.

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1. Introduction

Humans show a remarkable capacity for using tools and objects.¹ Parents are often amazed by the speed whereby young infants learn to interact with novel objects, like a hammer, or an I-Pad or an I-Phone. As adults we continuously surround ourselves with objects that greatly extend our bodily and cognitive capabilities. Driving a car or riding a bike significantly increases our physical action radius; a mobile phone enhances our capacity for long-distance communication; and a calculator offloads the need for mental calculation. In addition, humans often use objects in a flexible and context-dependent way. For instance, a cup can be used for drinking, for storing small object parts or for catching a fly. An intriguing question is how our ability for the flexible and context-dependent use of objects comes about. Do we rely on long-term stored knowledge about the multiple actions that objects afford? How do we select the relevant knowledge for the task at hand? Is object knowledge represented in a multimodal format, or does it entail distributed representations across modality-specific sub-systems?

Many studies have investigated the development and the neurocognitive basis of tool use from a variety of different perspectives. Developmental studies have focused for instance on the question when and how infants acquire conceptual object knowledge, patient studies have identified the relation between brain damage and specific impairments in object use and neuroimaging studies have focused on the neural correlates of retrieving object-related information. Here we propose the concept of *action semantics* as a unifying conceptual framework to integrate these previous findings and to highlight current debates that span different research domains. Starting from the premise that being

¹ Previous authors have argued for a conceptual distinction between tools and objects (e.g. [1] Rothi LJG, Ochipa C, Heilman KM. A cognitive neuropsychological model of limb praxis. *Cogn Neuropsychol* 1991; 8:443–58) according to which *tools* are used to act upon recipient *objects* in the surrounding world (e.g. using a bottle opener to open a bottle). However, any given object can be used as a tool as well (e.g. opening a bottle with another bottle) and accordingly throughout this review we will use the terms ‘tool’ and ‘object’ interchangeably.

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