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Research Report

Sentence comprehension and simulation of object temporary, canonical and stable affordances

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ARTICLE INFO

Article history:
Accepted 13 November 2008
Available online 3 December 2008

Keywords:
Language grounding
Affordance
Mirror neuron
Canonical neuron
Embodiment

ABSTRACT

Two experiments investigate the effects of language comprehension on affordances. Participants read a sentence composed by either an observation or an action verb (Look at/Grasp) followed by an object name. They had to decide whether the visual object following the sentence was the same as the one mentioned in the sentence. Objects graspable with either a precision or a power grip were presented in an orientation affording action (canonical) or not. Action sentences were faster than observation sentences, and power grip objects were faster than precision grip objects. Moreover, faster RTs were obtained when orientation afforded action. Results indicate that the simulation activated during language comprehension leads to the formation of a "motor prototype" of the object. This motor prototype encodes information on temporary/canonical and stable affordances (e.g., orientation, size), which can be possibly referred to different cognitive and neural systems (dorsal, ventral systems).

1. Introduction

A recent body of work has revealed that words are not linked in an arbitrary way to their referents but are grounded in perception, action and in sensorimotor processes. According to the "embodied" theory of language comprehension, understanding a sentence regarding an object would entail a mental simulation of the situation the sentence describes. This implies that the same neural areas are recruited as those involved during perception and interaction with the object (Barsalou, 1999; Barsalou et al., 2003; Gallese and Lakoff, 2005; Glenberg, 1997; Glenberg and Robertson, 2000; Pecher and Zwaan, 2005; Pulvermüller, 2005; Zwaan, 2004). Much recent evidence obtained with response time studies (Borghi et al., 2004; Borreggine and Kaschak, 2006; Boulenger et al., 2006; Buccino et al., 2005; Scorolli and Borghi, 2007), with kinematic measures (Gentilucci and Gangitano, 1998; Glover and Dixon, 2002; Glover et al., 2004; Nazir et al., 2008), with eye tracking studies (Huettig and Altmann, 2005; Spivey and Geng, 2001; Tanenhaus et al., 1995), and with brain imaging studies (Grafton et al., 1997; Kellenbach et al., 2003; Kemmerer et al., 2008; Pulvermüller, 2003), suggests that words evoke perceptual and motor information regarding their referents. In particular, words, like visual stimuli, evoke object affordances (Gibson, 1979). Affordances are what the environment offers acting organisms. They pertain to both perception and action. In addition, they are neither properties of the object/environment nor of the acting organisms. Instead, they are intrinsically relational properties. For example, a door handle affords opening for us, but not for a baby. In addition, a handle does

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doi:10.1016/j.brainres.2008.11.064

not afford acting for a tree, which is not an acting organism. Thus, affordances are unique to a particular organism, to his/her body structure and bodily characteristics.

Various studies have shown that visual objects automatically evoke affordances (e.g., Creem-Regehr et al., 2007). For example, Martin et al. (1996) have demonstrated with PET that naming tools selectively activates a left premotor area which is typically involved while imagining grasping an object with the hand, as well as an area in the middle temporal gyrus that is involved in producing action words. On the behavioral side, much of the evidence showing that seeing objects activates affordances is obtained with compatibility paradigms (see for example Tipper et al., 2007). However, these studies have not clarified the hypothesis that there might be different kinds of affordances. Consider our interaction with an object. In order to grasp effectively an object we have to know how and where to grasp it. In the first case, we can refer to stable features of the object, such as its size and shape, which can be incorporated into an object representation, stored in memory; but in the second case, we have to refer to more temporary aspects that depend on the way in which the object is shown.

Tucker and Ellis (1998) asked participants to decide whether objects were upright or reversed. They found a compatibility effect between the handle orientation of objects, which was not relevant to the task, and the position of the response key (left, right). Their results show that seeing an object with a left- or a right-oriented handle activated object affordances, leading to the facilitation of responses with the ipsilateral hand. The result has been replicated by Phillips and Ward (2002) with a priming paradigm. They presented participants with a visual object prime such as a frying pan with a left- or right-oriented handle, oriented towards or away from the participants, or in a neutral position. The prime was followed, after a varying SOA, by an imperative target requiring a response with the left or right hand or a foot-press. They found a compatibility effect between handle orientation and the key to press. This effect increased with SOA and slightly increased when the handle pointed towards rather than away from the observer. These results demonstrate that visual affordances (e.g., the object handles) potentiate lateralized responses corresponding with a given orientation of the affordances.

In our framework, orientation can be considered an example of a temporary affordance. Namely, orientation varies depending on the object's visual presentation. It does not represent a permanent characteristic of the object. For example, we might know that frying pans have a handle that we must grasp in order to use them, but information concerning the current orientation of the handle has to be processed online. However, there might be some kinds of orientation that are associated with the canonical interaction with and/or use of the object (Palmer et al., 1981; Riddoch et al., 2006). Thus, we will define orientation in general as a temporary affordance, but the typical orientation with which we interact with objects – for example, the typical orientation with which we read a book – as a canonical affordance. Thus, we claim that there might be different kinds of affordances: stable affordances, such as shape and size, and temporary affordances, such as orientation. Within temporary affordances, there might be canonical and non-canonical affordances: that is a given orientation might be more typical than others.

Similar compatibility effects have been found with stable affordances such as object size. Ellis and Tucker (2000) found a compatibility effect between object size and the kind of grip used to respond whether or not the objects were artefacts or natural objects. Participants responded faster in the case of objects graspable with a power grip by mimicking a power grip with a device, and to objects graspable with a precision grip by mimicking a precision grip. Borghi et al. (2007) found that priming a hand shape (power, precision) facilitated responses in the case of objects graspable with the same kind of grip, provided that participants first were trained to associate their own movements with the postures of the priming hand. These results suggest that seeing objects of different sizes activated information on how to grasp them (precision or power grip), even if this information was not relevant to the task at hand. The compatibility effects are due to information stored in memory rather than to online processing of visual information; the fact that the result obtained by Tucker and Ellis has been replicated in an experiment using words serves as further confirmation (Tucker and Ellis, 2004). Ellis and Tucker refer to the potentiated elements of an action as "micro-affordances". Microaffordances are brain assemblies that represent objects; they are the product of the conjoining, in the brain, of visual responses and action-related responses that have developed throughout individual and species history, i.e. through both ontogenesis and phylogeny, as part of the process of adapting to the environment. The reported studies on compatibility and affordances leave open the question as to whether or not temporary/canonical and stable affordances, such as orientation and size, can be dissociated. Our paper aims to disentangle the role played by these different kinds of affordances during sentences comprehension.

In order to investigate this issue, we used a picture recognition task. Participants were presented with either an observation or an action verb (Look at/Grasp) followed by an object name. They had to decide whether the visual object following the sentence was the same as the one mentioned in the sentence. Objects graspable with either a precision or a power grip were presented in both a canonical and not-canonical orientation (see Fig. 1). Following the embodied theory of language comprehension, we predict faster responses evoked by action rather than observation sentences, because the former rather than the latter sentences imply a physical interaction with the object involving the response effector. In addition, the task used invites to provide a judgement on the object, thus it probably renders the object characteristics particularly salient. Recent evidence (Bub et al., 2008) shows that a simple object noun activates both functional and volumetric affordances. According to the authors, functional affordances refer to using an object for its purpose, whereas volumetric ones refer to picking up the object.

Therefore, we predict that comprehending both an observation and an action sentence should lead to the formation of a "motor prototype" of the object, which encodes information on different affordances, and that the action sentences should have an advantage because both the noun and the verb involve an action hand.