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# Electrophysiological study of action-affordance priming between object names

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ABSTRACT

If our central representation of an object is defined through embodied experience, we might expect access to action affordances to be privileged over more abstract concepts. We used event-related potentials to examine the relative time course of access to affordances. Written object names were primed with the name of an object sharing the same affordance as the target (e.g. precision-grip: "grape" primed by "tweezers") or the same taxonomic category (e.g. fruit: "grape" primed by "apple"). N200 latencies, related to go/nogo semantic category decisions on target words, revealed no difference in facilitation provided by affordance and semantic priming. However, separate analyses of ERPs for go and nogo trials showed that semantic priming led to earlier activation during go trials (around 430 ms), and affordance priming led to earlier activation during nogo trials (around 180 ms). While affordances appear to be peripheral to the conceptual representation of objects, they do lead to direct motor preparation.

## 1. Introduction

The majority of the embodied cognition literature has focused on the sensorimotor processes involved in processing action words and sentences. However, it is also thought that the name of an object will also recruit the sensorimotor brain activity associated with the referent's form and function, such as its action affordances (Bub & Masson, 2012). Affordances are the behavioural possibilities provided by the environment and are detected automatically by the visual system, regardless of the organism's intention to act (Garbarini & Adenzato, 2004; Gibson, 1979). For example a mug affords being grasped with the hand (Withagen, de Poel, Araújo, & Pepping, 2012). The Indexical Hypothesis proposes that nouns are indexed to mental representations (such as mental pictures) of the objects they refer to (Glenberg & Robertson, 1999). Subsequently, when a noun is processed the affordances of the referent object are made available. According to the Indexical Hypothesis accessing the affordances of referent objects is crucial for noun comprehension (Glenberg & Gallese, 2012; Glenberg & Robertson, 1999). A number of behavioural studies support the idea that affordances are retrieved during object name processing (Barbieri, Buonocore, Bernardis, Dalla Volta, & Gentilucci, 2007; Bub & Masson, 2012; Bub, Masson, & Cree, 2008; Gentilucci & Gangitano, 1998; Glover & Dixon, 2002; Glover, Rosenbaum, Graham, & Dixon, 2004; Marino, Gough, Gallese, Riggio, & Buccino, 2013; Myung, Blumstein, & Sedivy, 2006; Tucker & Ellis, 2004). Participants are quicker to make categorical judgements when responding with a hand-grip that would be used to interact with the referent object (Tucker & Ellis, 2004; experiment 3). Furthermore, reading the name of a manipulable object activates areas of the premotor cortex which are also involved in action word processing (Grabowski, Damasio, & Damasio, 1998).

While the interaction between motor and language processing is well evidenced, the utility of this relationship is an area of considerable controversy. There seems to be little doubt that linguistic representations of actions and affordances can generate motor activity, but it is unclear what, if any, role this activity plays in language comprehension (Chatterjee, 2010; Dove, 2009, 2011; Mahon & Caramazza, 2008). Mahon and Caramazza (2008) argue that findings purported to support embodied cognition could just as easily be explained by a disembodied account. They propose that an initial retrieval of abstract concepts is followed by the spreading of activation to sensory and motor areas, with these activations reflecting a later epiphenomenal process, such as mental imagery. Language and situated simulation (LASS) theory proposes that two systems are involved in language comprehension (Barsalou, Santos, Simmons & Wilson, 2008). The Linguistic system identifies the word form and the simulation system activates perceptual and experiential information associated with the object, such as its affordances. The linguistic system is sufficient for resolving tasks that only require shallow processing, involving statistical relations between words in a semantic network (words associated through frequent co-occurrence). For deep and meaningful processing, simulations are

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necessary and these are activated automatically, within 200 ms after word onset. It is important to understand when, and by implication what stage of processing, language perception makes use of embodied representations. If they are fundamental to the conceptual representations of objects it might be expected that they would be available in advance of more abstract information. This kind of temporal information can be difficult to ascertain with behavioural experiments, but is particularly well suited to the ERP technique. Amsel, Urbach and Kutas (2013) used this technique to determine the temporal order of access to abstract and motor related semantic information when presented with the names of objects. Using a go/nogo task they compared the temporal onset of the N200 component when participants were asked to make a judgment on whether objects were graspable or non-graspable, or whether they were living or non-living. The N200 is a negative going component resulting from the subtraction of go from nogo trials, and is thought to provide an indication about when sufficient information has become available to allow a participant to make or withhold their response (Augustin, Defranceschi, Fuchs, Carbon, & Hutzler, 2011). Amsel et al. (2013) found that the onset of the N200 related to a living/non-living judgment was at around 160 ms after stimulus presentation, compared to 300 ms for the graspable/non-graspable judgment. The relatively late access to grasp-related affordances prompted the authors to conclude that they did not play a crucial role in the conceptual representation of objects.

Although the results provided by Amsel et al. (2013) seem relatively clear, they are based upon the assumption that the participant has direct access to the information relevant to this explicit decision. However, affordances are generally considered to be processed automatically as a component of object representation that provides implicit facilitation of a wide range of responses (Barbieri et al., 2007; Glover et al., 2004; Marino et al., 2013; Myung et al., 2006; Pulvermüller, Shtyrov, & Ilmoniemi, 2005; Tucker & Ellis, 2004). For example, Glover et al. (2004) found that when participants went to grasp a wooden block, the aperture of their grip was larger when they read a word referring to a large object than a small object. Another study found that when participants heard the names of objects they spent longer looking toward pictures of objects that shared similar manipulation features with the named object than those that did not, with affordance-related looking occurring as early as 300 ms (Myung et al., 2006; experiment 2). As it has been established that affordance modulates behaviour without the awareness of the participant, it is possible that the earliest access to this property may not be revealed through explicit questioning.

In our study we wanted to capture the implicit effects of affordance in an ERP study similar to that of Amsel et al. (2013). However, instead of comparing the N200 related to different explicit judgment decisions, i.e. those based on semantic and affordance information, we examined how the N200 related to the same semantic decision would be modulated by priming. Semantic priming effects are well established in the literature (Lucas, 2000), with priming found to improve both the accuracy and reaction times in lexical decision tasks (Meyer & Schvaneveldt, 1971). This facilitation is also found when the prime is masked (e.g. Forster & Davis, 1984), that is when presented for a very short duration (50–60 ms), usually sandwiched between two visually obscuring forward and backward masks. This is designed to allow the investigation of the prime-target relationship without the awareness of the participant, so preventing the use of explicit response strategies. Studies using the ERP technique have shown that semantically related prime-target pairs elicit a smaller N400 than semantically unrelated prime-target pairs (Deacon, Hewitt, Yang, & Nagata, 2000; Kutas & Federmeier, 2011). This is thought to reflect the greater ease in which the target is integrated into the semantic context provided by the prime (Borovsky, Elman, & Kutas, 2012). In most studies, the semantic relatedness between prime and target is determined by semantic category norms, such as those of Battig and Montague (1969), which largely shared a taxonomic relationship (e.g. steel and iron being "types of metal"). There are few studies that have examined the relationship between objects formed by a shared affordance. In one such study by Myung et al. (2006), auditory prime and target words either shared similar manipulation features (e.g. piano and typewriter) or not (e.g. piano and blanket). This study showed that shared affordances facilitated reaction times, but did not provide any direct comparison with the facilitation provided by taxonomic semantic priming.

Here we have used the masked priming paradigm to compare the relative differences in priming between written prime-target word pairs that are related either through taxonomy (e.g. "grape" and "banana" are both fruit) or affordance (e.g. "hammer" and carrot" are both manipulated using a power-grip). Both of these related priming conditions were also compared to a baseline condition, where the prime did not share the same taxonomy or affordance with the target (e.g. "mushroom" and "drill"). These word pairs were used in a go/nogo task to evoke an N200 component related to a speeded natural/manmade decision on the target words. An estimate of the temporal onset of affordance and general semantic information was provided through a comparison of the N200 between the three priming conditions. If the sensorimotor activity associated with affordances is fundamental to object representation, then we would hypothesise that the facilitation provided by the priming of affordances should occur earlier than that of semantic priming. Conversely, if affordances are produced as part of a post-lexical mental simulation of object use or accessed via an amodal process of spreading activation we would expect that the temporal onset of this information should occur after semantic processing.

## 2. Method

### 2.1. Participants

Sixty native monolingual English speakers gave informed, written consent to participate in the experiment and were paid £12 for their participation. The Data from 9 participants was discarded due to excessive EEG and electrooculography (EOG; eye movements) artefacts (less than 66% of recorded trials available for analysis). The remaining 51 participants (32 female) were aged between 18 and 32 (mean age = 21.76). All participants were right-handed (as assessed with the Edinburgh Handedness Inventory; Oldfield, 1971), reported having normal or corrected-to-normal vision and had no history of neurological impairment.

### 2.2. Stimuli

The critical stimuli consisted of 32 different concrete nouns (taken from the CELEX database; Baayan, Piepenbrock, & Gulikers, 1995) referring to manually manipulable objects. Sixteen of the nouns were used as prime words (3–10 letters in length) and 16 were used as the target words (3–6 letters in length). Half of the prime words referred to natural objects and half referred to manmade objects. Within each of those categories, half were the names of objects affording a power-grip (e.g. "hammer" or "carrot") and half were names of objects affording a precision-grip ("scalpel" or "grape"). The target words were a different set of 16 nouns that were also equally divided between these four categories (manmade power-grip; manmade precision-grip; natural power-grip; natural precision-grip).

Each prime word was paired with each target word so that there were 256 prime-target pairs. There were three conditions: *semantic* (when the prime and target referred to objects that were taxonomically related but did not afford the same grip e.g. 'strawberry-banana' or 'potato-pea'); *affordance* (when the prime and target referred to objects that afforded the same hand grip but were not taxonomically related e.g. 'tweezers-lentil' or 'orange-axe'); or *neutral* (when the prime and target referred to objects that were neither semantically related nor afforded the same grip e.g. 'fig-hammer' or 'scalpel-apple'; see Appendix for a full list of the stimuli). There were 64 different prime-

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