Visual Hand Primes and Manipulable Objects

Anna M. Borghi (annamaria.borghi@unibo.it)
Department of Psychology, Viale Berti Pichat, 5
Bologna, 40127 Italy

Claudia Bonfiglioli (claudia.bonfiglioli@unitn.it)
Department of Cognitive Science and Education, Via Matteo del Ben, 5
Rovereto (Trento), 38068 Italy

Luisa Lugli (lugli@dsc.unibo.it)
Department of Communication Disciplines, Via Azzo Gardino, 23
Bologna, 40122 Italy

Paola Ricciardelli (paola.ricciardelli@unitn.it)
Department of Cognitive Science and Education, Via Matteo del Ben, 5
Rovereto (Trento), 38068 Italy

Sandro Rubichi (rubichi@unimo.it)
Department of Social, Cognitive and Quantitative Sciences, via Giglioli Valle, 9
Reggio Emilia, 42100 Italy

Roberto Nicoletti (nicoletti@dsc.unibo.it)
Department of Communication Disciplines, Via Azzo Gardino, 23
Bologna, 40122 Italy

Abstract

In three experiments we assessed whether priming a hand shape activated motor information. Primes consisted of photographs of hands displaying one of three postures (precision, power, open hand). Targets consisted of photographs (Experiment 1 and 3) or words (Experiment 2) of objects, artifacts and natural kinds, manipulable with a precision (pencil) or with a power grip (bottle). Participants had to categorize objects into artifacts or natural kinds by pressing a different key. They had to respond to target-objects only when the targets followed the precision and the power primes, while they didn't have to respond when the targets followed the open hand (catch-trial). In Experiments 1 and 2, artifacts were processed slower than natural kinds, and natural kinds graspable with a power grip were processed faster than those graspable with a precision grip. These results confirm that visual primes activate general motor information on objects. However, only in Experiment 3, in which a motor training phase lead participants to associate a specific visual prime with a motor action, we found an interaction between Kind of Prime (precision, power) and Kind of Grip (precision, power grip). Results suggest that vision and motor information are strictly interwoven and support theories according to which object concepts are grounded in sensorimotor experience.

Introduction

A recent account of conceptual knowledge suggests that information is distributed over modality attribute domains (visual, tactile, auditory, etc.) and that these domains are more or less activated depending on their relevance during knowledge acquisition (Barsalou, 1999; Boronat, Buxbaum, Coslett, Tang, Saffran, Kimberg, Detre, in press; Pecher, Zeelenberg, & Barsalou, 2003). In line with this account, various evidence on cortical object representation has been provided (e.g., Zago, Fenske, Aminoff, & Bar, 2005). In addition, Martin, Wiggs, Ungerleider, and Haxby (1996) reported greater activation of left premotor cortex in naming tools relative to naming animals and in generating action words to tools. This account leads to the prediction that manipulable artifacts (e.g., knife) and manipulable natural kinds (e.g., apple) differ as the first are typically manipulated for a specific use, the second are not necessarily associated to a specific function. So, for example, a hammer is typically used to hammer nails, whereas a flower does not have such a specific function.

Consistent with this theory is evidence showing that visual stimuli activate motor information, i.e. seeing an object re-activate previous action experiences with that objects. An experiment supporting the view that there is a strict relationships between specific visual stimuli and specific motor actions was performed by Craighero, Bello, Fadiga and Rizzolatti (2002). They instructed participants to prepare to grasp a bar, which could be oriented either clockwise or counterclockwise, and to grasp it as fast as possible on presentation of a visual stimulus. The visual stimuli were pictures of the right hand as seen in a mirror. Reaction times (RTs) were faster when there was a similarity between hand position as depicted in the triggering visual stimulus and the response position, i.e. the grasping hand final position. Behavioral studies with compatibility paradigms, i.e. paradigms implying some kind of dimensional overlap between stimuli and responses, indicate that the vision of objects elicits motor information, related in particular to reaching and grasping movements (Tucker & Ellis, 1998). For example, participants were instructed to press a switch mimicking a precision or a power grip in order to decide whether objects were natural kinds or artifacts. Results showed they were faster in responding with a precision grip to both artifacts and natural kinds objects graspable with a precision grip, such as pencils and cherries, and faster in responding with a power grip to objects graspable with a power grip, as for example hammers and apples (Ellis & Tucker, 2000; Tucker & Ellis, 2001).

Notice that the behavioral studies showing a relationship between specific visual stimuli and specific motor responses typically require a preactivation of the motor system. For example, Craighero et al. asked participants to grasp a bar, whereas Tucker & Ellis asked them to press a device mimicking either a precision or a power posture. In our experiments we chose to avoid pre-activating the motor system and used a simple categorization task - participants had to press a different key to decide whether objects represented by photographs (Experiment 1 and 3) or referred to by words (in Experiment 2) were artifacts or natural kinds. All objects were manipulable ones, half were graspable with a power grip (e.g., apple), and half with a precision grip (e.g., cherry). The objects were preceded by a visual prime consisting of a hand mimicking either a power or a precision grip.

If information on object manipulability is automatically evoked when seeing objects, particularly when objects are preceded by a visual hand prime activating information on grasping, then we predict that:

a. objects which do not imply access to function but only to action, as natural kinds, should be processed faster than objects linked to functional information, as artifacts (Kellenbach, Brett & Patterson, 2003)**;**

b. larger objects should be processed earlier than small objects as the latter require more time to be manipulated.

In addition, if specific information on how to manipulate objects is automatically activated when viewing a hand suggesting a specific kind of grasp, then the response should be affected by compatibility between the hand posture and the way in which be object can be grasped, i.e. either with a precision or with a power grip. Experiment 1

Method

Participants Fourteen students of the University of Bologna took part in the experiment. All were right-handed and received course credits for their time.

Materials Digital photographs of a human hand displaying one of three different postures (precision, power, open hand) (see Figure 1) and 64 photographs of manipulable objects, 32 artifacts and 32 natural kinds, were selected. All photos represented objects of the same size, independent from objects' real size (for example, apples were smaller and nuts larger than they are in real life). A special care was taken in selecting everyday, common and familiar objects. The majority of the items were taken from the set used by Ellis and Tucker (2000) and Tucker and Ellis (2001). Half of the chosen artifacts and natural kinds were objects which are graspable with a precision grip (e.g., pencil, nut), the other half were objects which are graspable with a power grip (e.g., bottle, apple).

Procedure Participants sat in front of a computer monitor. Each trial began with a fixation point (+) displayed on the monitor for 500 ms. When the fixation cross disappeared, one of the three hand photographs was displayed. The prime was followed by the target consisting of the photograph of one object. When the prime consisted of a hand mimicking a precision or a power grip, participants had to press a different key to decide whether the target object was an artifact or a natural object. When the prime depicted an open hand (catch-trial), participants had to avoid responding to the target. Participants received feedback both for correct and for wrong responses. All stimuli were displayed centrally on the monitor and randomized. Each object was seen four times by each participant, each time preceded by a different hand prime. The experiment consisted of one practice block of 48 practice trials and of one experimental block.

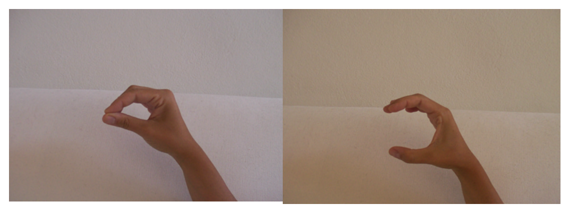

Figure 1: The precision and the power hand grip.

Results

Reaction times more than 2 standard deviations from each participant's mean were excluded from this analysis and the analysis of all other experiments reported. Analyses of errors revealed no evidence of a speed accuracy tradeoff, so we focused on RTs analyses. In the participants' analysis correct RTs were entered into a 2x2x2 ANOVA with the following factors, manipulated within participants: Kind of Prime (precision, power), Kind of Target (artifact, natural kind), and Kind of Grip adequate for the target object (precision grip, power grip).

Responses to natural kinds were 15 msec faster than responses to artifacts, though results only approached significance [$F(1, 13) = 3.66$, $MSe = 1743.7$, $p < .08$].

More interestingly, the interaction between Kind of Target and Grip was significant[$F(1, 13) = 8.39$, $MSe = 477.21$, $p < .02$] (see Figure 2). Newman-Keuls post-hoc analyses showed that this was due to the fact that with natural kinds objects graspable with a power grip were faster than both natural kinds graspable with a precision grip and all artifacts.

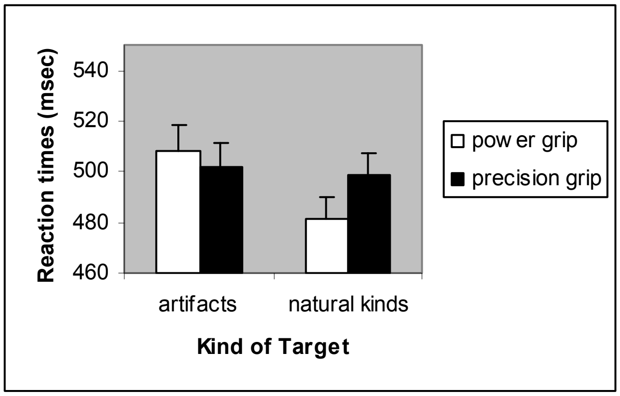

Figure 2: Experiment 1. Interaction between Kind of Target and Kind of Grip.

Discussion

The results provide evidence that even with a simple categorization task, i.e. with a task which does not require a pre-activation of the motor system, objects primed by a hand in a grasping posture activate motor information. The activation of motor information explains the advantage of natural kinds over artifacts which might be due to the fact that the latter evoke both manipulation and function information. A further cause of the longer RTs required by artifacts is that with artifacts information on manipulation and on function may differ: for example, a hammer might be grasped in different ways to be moved and to be used to hammer a nail. As predicted, objects graspable with a power grip were processed faster than objects graspable with a precision grip. It could be argued that the effect is a purely perceptual one, not linked to manipulation and action: for example, Kosslyn (1976) has shown that, in a part verification task with objects' nouns, large parts were responded to faster than small ones when participants formed a mental image of the object before responding. However, the presence of the effect only with natural kinds rules out this possible objection: the more plausible explanation links the effect to the fact that natural kinds evoke motor information on grasping, while artifacts evoke also function information. Further controls however are planned in order to better disentangle this issue.

The absence of the compatibility effect between the Kind of Prime and the Kind of Grip lead to exclude that a specific visual prime, i.e. an hand with a specific posture, activates specific motor information. However, our results provide evidence that some kind of motor information was activated. Experiment 2 was aimed to determine whether this activation was directly evoked by the visual stimuli or whether it was mediated by conceptual knowledge. In order to verify this in Experiment 2 instead of photographs we used words referring to objects. If we find similar effects, then we can argue that not only visual stimuli but also object names activate motor information. This would suggest that the effects found depend on the activation of conceptual information rather than simply on affordances (Tucker & Ellis, 2004).

Experiment 2

Experiment 2 was an exact replica of Experiment 1 with verbal rather than with visual stimuli. If the results we find were similar to that of Experiment 1, we could argue that also words activate motor information (Borghi, Glenberg & Kaschak, 2004). In addition, finding activation of motor information also with words would suggest that it does not depend only on the direct vision-to-action route, but that access to conceptual knowledge contributes to explain it.

Method

Participants Fourteen students of the University of Bologna took part in the experiment. All were right-handed.

Materials The material was the same of Experiment 1. The only variation introduced were the object photographs which were substituted by the object names.

Procedure The procedure was identical to that of Experiment 1. The only variation consisted in the fact that the targets consisted of object names rather than photographs.

Results

One participant was eliminated due to a too high number of errors. As in Experiment 1, the main effect Kind of Target was significant: natural kinds were responded to 41 msec faster than artifacts [$F(1, 12) = 8.99$, $MSe = 4924.65$, $p < .02$]. In addition, objects graspable with a power grip were 19 msec faster than those graspable with a precision grip [$F(1, 12) = 12.53$, $MSe = 728.17$, $p < .01$]. The advantage of objects graspable with a power grip over objects graspable with a precision grip was stronger for natural kinds, as revealed by the interaction between Kind of Target and Grip [$F(1, 12) = 26.65$, $MSe = 692.24$, $p < .001$] (see Figure 3).

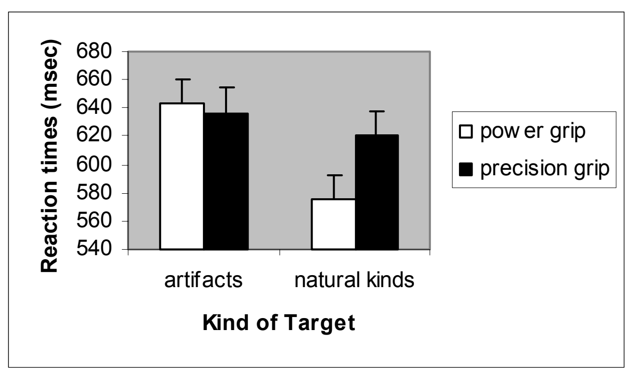

Figure 3: Experiment 2. Interaction between Kind of Target and Kind of Grip.

Crucially, also the interaction between Kind of Prime and Kind of Target was significant, due to the fact that response times were longer with artifacts names preceded by the precision prime than by the power prime and than by natural kind names [$F(1, 12) = 5.72$, $MSe = 3806.71$, $p < .04$] (see Figure 4).

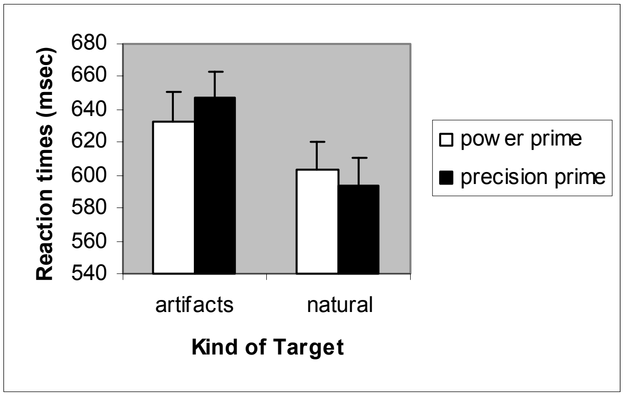

Figure 4: Experiment 2. Interaction between Kind of Prime and Kind of Target.

Discussion

The results confirm what found in Experiment 1, showing that not only seeing but also reading words referring to everyday objects activates motor information. As in Experiment 1 natural kinds were processed faster than artifacts, probably due to the absence of an interference between motor and function information. In addition, natural kinds graspable with a power grip were processed faster than both artifacts and natural kinds graspable with a precision grip.

This is perfectly consistent with theories assuming that concepts are grounded in sensorimotor activity (Barsalou, 1999) and with theories and experimental results on language comprehension showing that, while comprehending action sentences, we internally "simulate" the action described reactivating the real experience (Glenberg & Kaschak, 2002; Kaschak, Madden, Therriault, Yaxley, Aveyard, Blanchard, & Zwaan; Zwaan, 2004). In this case the object name and the visual prime lead participants to form an internal simulation of object grasping. The "simulation" hypothesis is supported by the effects of prime, which was different for artifacts and natural kinds. In fact, grasping objects with a precision prime requires more time. This is true especially for artifacts as the precision grip is typically used for skilled actions related to object function (consider for example how we generally grasp a pencil in order to write with it).

Experiment 3

The rationale behind Experiment 3 was the following. The first two experiments provided evidence that viewing objects automatically activates some kind of motor information. Even though we found clear evidence of the activation of motor information, we did not find evidence of specific effects of the two different visual primes, i.e. there was no compatibility effect between the Kind of Prime and the Kind of Grip adequate for the target object. Two explanations are possible. The first is that participants did not pay enough attention to the prime. However, the very low percentage of errors made when the catch-trial was presented rules out this explanation suggesting that participants processed the prime. Also the interaction we found between Kind of Prime and Kind of Object found in Experiment 2 suggests that the prime was processed. The second explanation is that, even if the visual prime elicited information concerning manipulability, it was not sufficient to activate a specific kind of motor information. Accordingly, even if both visual cues activate general information related with object "grasping", each prime did not evoke a specific kind of grasp, i.e. a precision vs. a power grasp.

In order to test whether the visual prime alone was not sufficient to evoke specific manipulation information, in Experiment 3 we introduced a training phase that preceded the experiment in which each visual prime was associated with a specific motor response. During training participants saw in a random order both the power and the precision primes, and had to reproduce with both hands the gestures seen. Our prediction was that, if during the training phase participants learned to associate a specific visual stimulus with a specific gesture, then simply seeing the visual stimulus would automatically activate information on the specific motor response associated to it.

Method

Participants Thirty students of the University of Bologna took part. All were right-handed.

Materials Materials were the same of Experiment 1. In addition a list of 30 trials was prepared with 15 photographs of the hand in the precision posture and 15 of the hand in the power posture.

Procedure The procedure of the experiment was identical to that of Experiment 1. The only variation consisted of the introduction of a training phase. During the training the two hand photographs displaying the precision and the power posture were shown in a random order for 15 times each, for a total of 30 trials. Participants were instructed to reproduce with both hands the gesture of the photograph on the screen. An experimenter controlled that participants correctly performed the task. After the training phase, participants started the experiment.

Results

The data of one participant were eliminated due to a too high number of errors. As in the previous experiments, the main effect Kind of Target was significant: natural kinds were responded to 24 msec faster than artifacts [$F(1, 29) = 9.76$, $MSe = 3471.33$, $p < .01$]. Also the interaction between Kind of Target and Kind of Grip was significant in the participants analysis [$F(1, 29) = 7.96$, $MSe = 4500.84$, $p < .01$] due the fact that natural kinds objects graspable with a power grip were faster than natural kind objects graspable with a precision grip and than artifacts (see Figure 5). As in Experiment 2, there was an interaction between the Kind of Prime and the Kind of Concept, which only approached significance [$F(1, 29) = 3.19$, $MSe = 3879.38$, $p = .08$;] Again, with artifacts the precision prime was slower than the power prime, suggesting that information about function slows down processing. The most interesting result was the expected interaction between Kind of Prime and Kind of Target [$F(1, 29) = 4.05$, $MSe = 2295.60$, $p = .05$]. (see Figure 6). Post-hoc Newman-Keuls indicated that the interaction was due to the fact that the power prime followed by a target graspable with a precision grip required longer RTs than other cases. The presence of this effect suggests that participant, due to the training, became sensitive to the compatibility between the prime and the target. It is not clear why we did not find a processing disadvantage also for the other incompatible pair, i.e. the pair given by the precision prime followed by a target graspable with a power grip. It may be due to the fact that, even though photographs referred to objects manipulable either with a precision or with a power grip, in the photos objects were presented with a standard size – for example, strawberries are of the same size as hammers.

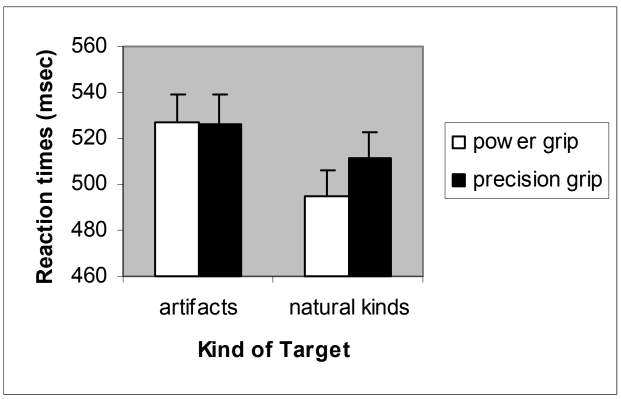

Figure 5. Experiment 3. Interaction between Kind of Target and Kind of Grip.

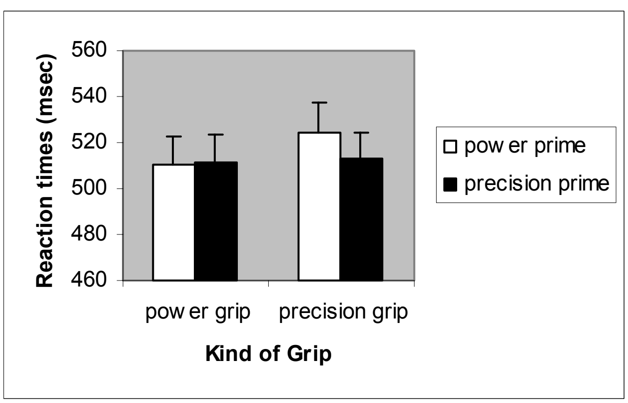

Figure 6. Experiment 3. Interaction between Kind of Prime and Kind of Grip.

Discussion

The results of Experiments 1 and 2 suggested that priming a hand shape elicits general motor information on object manipulability. However, the precision prime and the power prime did not activate a specific kind of motor information. Experiment 3 showed that specific information related to the kind of grip could be activated only when the two visual primes were associated during a training phase with two specific gestures. This suggests that visual primes alone are not sufficient to evoke motor information of a specific kind, unless they are combined with a pre-activation of the motor system.

General Discussion

The experiments provide evidence of the activation of motor information. Across 3 experiments we found that the visual prime activated motor information, i.e. general information on how to manipulate objects. The processing advantage of natural kinds over artifacts can be easily accounted for by theories according to which conceptual knowledge information is distributed over modality attribute domains. Namely, whereas natural kinds activate visual and motor information, artifacts elicit also function information. Studies on conceptual organization have shown that the recognition of artifacts depends more on functional features than the recognition of natural objects (Warrington & Shallice, 1984). In addition, recent neuropsychological studies suggest that action and function information might differ (Buxbaum, Veramonti, & Schwartz, 2000; Kellenbach et. al, 2003). Thus, longer RTs with artifacts may be due to the fact that artifacts evoke both manipulation and function information, and that the two kinds of information may be dissociated, whereas this is not the case for natural kinds. An alternative explanation is also possible: Humphreys, Riddoch and Forde (2002) propose that in categorization tasks natural kinds are responded faster than artifacts because of their higher perceptual similarity – an apple and a flower are more similar to each other than, say, a hammer and a pencil. However, also in this second case a higher within category similarity is grounded in the similarity of possible motor responses.

The faster responses with objects graspable with a power grip than with objects graspable with a precision grip represent a further proof of the activation of motor information, even if this effect was confined to natural kinds. The result is consistent with the simulation hypothesis: given that a precision grip requires more time than a power grip, the same is true when we internally simulate the grasping action. The striking similarity of the results obtained with photographs and with words suggests that the activation of motor information is not directly evoked by the visual stimuli but it is mediated by conceptual knowledge. Consistent with this hypothesis is recent evidence by Creem and Proffitt (2001) who found that conceptual information was necessary in order to accomplish appropriate actions with objects. Performing semantic tasks of different difficulty levels interfered with the primary task consisting in grasping appropriately objects with a handle, whereas nonsemantic tasks did not interfere with the grasping task. This suggests that retrieval of semantic information about an object is a necessary component of grasping objects in an appropriate manner. In line with these results Tucker & Ellis (2004) recently found affordance compatibility effects between object size and kind of grip also with object names (see also Pecher & Zwaan, 2005).

The described results allow to argue that the visual prime elicited general information on manipulation both when targets consisted of objects photographs or of object names. However, without preactivation of the motor system we did not find a specific effect of the two different prime postures on object processing. Only in Experiment 3, in which during training participants learned to associate the specific visual primes with specific gestures, they re-activated the gestures while processing the prime. This is consistent with previous evidence. For example, Klatzky, Pellegrino, McCloskey, & Doherty (1989) assessed whether priming a hand shape facilitated judgments about the sensibility of actions performed with objects. They found compatibility effects between 4 postures and action sentences – for example, the sentence "aim with a dart" was processed faster when preceded by a pinch posture than by other postures. Crucially, in Klatzky et. al 's study before the experiment participants learned to associate the prime, which could be presented either visually or verbally, to a specific gesture they had to perform. The different results of Experiment 1 and 2 and of Experiment 3 suggest that in order to activate specific motor information, i.e. information on the specific posture to adopt for a given object, it is necessary to pre-activate the motor system. This can be done associating a specific visual stimulus to a specific motor response. An alternative is possible. In these experiments we chose to present a visual prime which was not "dynamic": the hand was presented in a static, horizontal posture. It is possible that rendering the visual prime more evocative and dynamic or manipulating the perspective of the hand prime, as suggested by a recent study by Vogt, Taylor & Hopkins (2003), could lead to activate specific motor information even without a pre-activation of the motor system. Further experiments are planned in which the visual presentation of the prime will be manipulated.

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