Do we access object manipulability while we categorize?

Evidence from reaction time studies.

Anna M. Borghi*, Claudia Bonfiglioli^, Paola Ricciardelli^, Sandro Rubichi~ and Roberto Nicoletti*

University of Bologna*

University of Trento – Rovereto^

University of Modena and Reggio Emilia~

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Address for the correspondence:

Anna M. Borghi

Dipartimento di Psicologia, Università di Bologna

Viale Berti Pichat, 5 - 40127 – Bologna

phone: +39-051-2091838, fax: +39-051-243086

e-mail: annamaria.borghi@unibo.it

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Abstract

In two experiments we investigate whether different decision tasks were influenced by object manipulability. In Experiment 1, participants had to categorize objects represented by drawings or by words into artefacts or natural kinds. Natural objects received faster responses than artefacts, probably because the latter activate functional information that interferes with task responses. In Experiment 2, manipulability was made relevant to the task by asking participants to categorize items into two categories depending on whether or not they could be picked up and put inside a backpack. The disadvantage of artefacts over natural kinds was still found. Intriguingly, now an effect of manipulability was also found, but only with natural kinds, probably due to the fact that they convey information associated both with action ("how") and function ("what for"). The same pattern of results found with drawings and words suggests that also words activate motor information on how to grasp objects.

Introduction

How we manipulate and interact with objects has been a long-standing research issue that is still far from being settled. Not only we need information on how to grasp objects but also on how to use them. In other words, we learn *how* to hold a knife and *what* it is for. It is still a matter of debate whether these two different notions are represented separately or are embodied together in object concepts (for reviews see Borghi 2005; Carlson and van der Zee 2005; Coventry and Garrod 2004).

Studies on conceptual organization have shown that categories differ in the weight they put on different types of knowledge: the recognition of artifacts depends more on functional features (e.g., cup – used to drink) than the recognition of natural objects (e.g., dog) (Warrington and Shallice 1984). However, while the notion of "visual" features is fairly clear (i.e. shape, color, etc.), the notion of “functional” feature is under defined, as it may either include either action or function information or both (Borghi 2004).Recent neuropsychological studies suggest that action (“how”) and function (“what for”) information, i.e. information on how to manipulate and interact with an object and information on how to use it properly, might differ. Crucially, recent neuropsychological studies suggest that action and function information might differ. Buxbaum, Veramonti and Schwartz (2000) report cases of apraxic patients with impaired manipulation knowledge but intact function knowledge. These cases double dissociate from a case of an agnosic patient who was able to determine how to manipulate certain objects, but was not able to define their function or the context in which they would be utilized (Sirigu, Duhamel, and Poncet 1991). Brain activation results showed that the response of the left ventral premotor cortex and the left middle temporal gyrus was stronger for manipulable than for non-manipulable objects, whereas no regions of the cortex were more activated by function relative to action judgements about artifacts (Kellenbach, Brett and Patterson 2003). These results indicate that the brain responds preferentially to how we interact with objects, rather than to what they are used for, and suggest that action and function knowledge do not overlap.

Other functional neuroimaging studies have shown that action information is automatically activated by viewing objects and pictures, and that the same areas are involved when forming motor imagery and when activating information on tools. In a PET study Martin, Wiggs, Ungerleider, and Haxby (1996) found that naming tools, compared to naming animals, differentially activated the left middle temporal gyrus – an area nearly identical to the area activated by action generation tasks - and the left premotor cortex, an area generally activated when participants imagine themselves grasping objects with their dominant hand. Grafton, Fadiga, Arbib and Rizzolatti (1997) found that retrieval of actions associated with tools produced activation in the left premotor cortex. More recently, Chao and Martin (2000) carried out a fMRI study showing that the left premotor cortex responds selectively to photographs of tools but not to other objects such as animals, faces, and houses. Consider that this different activation pattern cannot be due to the distinction between artifacts and natural objects, nor can it be due to the fact that only tools are characterized by functional information – houses, too, are artifacts and have a specific function. In alternative, the selective response for tools might be due to the fact that, differently from the other considered categories, tools are manipulable objects. In a PET study Gerlach, Law and Paulson, (2002) showed that in a categorization task the left ventral premotor cortex was activated with both artifact and natural manipulable objects – more specifically, it was activated during categorization of fruit/vegetables and clothing, relative to animals and non-manipulable artifacts. Behavioral evidence on manipulability is sparser. Bub, Masson and Bukach (2003) showed photographs of hand gestures followed by the photographs of objects associated with the gestures (for example, pinch: match and needle). Participants had to depress a key until they started to gesture in response to the object color. No advantage of pairs in which the gesture associated with the color and the gesture typically associated to the object corresponded was found. The performance was better when the color and the gesture associated with the object corresponded only when a cue indicated whether to gesture to the color or to the object. This suggest that passively viewing an object does not necessarily imply the activation of gestural knowledge; this knowledge is recruited only when competing sources of gestural representations are activated.

Behavioral studies with compatibility paradigms, i.e. paradigms implying some kind of correspondence between stimuli and responses, indicate that the vision of objects elicits motor information, related in particular to reaching and grasping movements (Tucker and Ellis 1998; 2001; 2004). Ellis and Tucker (2000) and Tucker and Ellis (2001) asked participants either to respond to a high or a low tone or to categorize objects of different size located behind a screen as natural or artefact, using either a power grip or a precision grip. A compatibility effect between the kind of grasp and the object`s size was found. A similar compatibility effect was found between the direction of the wrist rotation and the kind of grasp required by the object: for example bottles facilitated responses with a clockwise wrist rotation, toothbrushes responses with a counter-clockwise wrist rotation. These compatibility effects were found regardless of whether the objects were natural or artifacts - they only depended on the way objects could be reached and grasped.

The studies reported leave some questions open. First, they demonstrate an automatic activation of information on grasping only when the motor system is pre-activated – for example, the response consists of different ways to grasp a device rather than of a simple key pressure. To our knowledge the only exception is the study by Saffran, Kossler and Keener (2003) who in a word association task found a higher proportion of verbs produced with pictures than with words and with manipulable than with not-manipulable objects. However, to our knowledge no study has investigated the effect of manipulability on the speed of processing of different concepts. Finding an effect of manipulability on response times would be important in order to verify whether information on how to interact with objects is part of our conceptual representation and directly affects behavior.

Second, these studies do not allow to clearly distinguish what kind of motor information is automatically activated – whether information on how to interact with objects or on how to use them.

Third, they leave open the question of whether or not compatibility results as those described imply access to conceptual knowledge. According to an influential account, two different routes to action exist: a direct vision-to-action route, mediated by on-line dorsal system processes, and a mediated vision-to-semantics-to-action ventral route (Castiello and Jeannerod, 1991; Fagg and Arbib 1998; Rumiati and Humphreys 1998). From this account it follows the prediction that pictures activate manipulation information more directly than words (Phillips, Humphreys, Noppeney and Price 2002). Consider that the fact that pictures activate motor information more directly than words does not necessarily imply that words do not activate motor information. Recent behavioral evidence suggests that also words activate motor information (Barsalou 1999; Glenberg and Kaschak 2002; Klatzky, Pellegrino, McCloskey and Doherty 1989; Pecher and Zwaan 2005; Pulvermüller 2003). Compatibility effects between object size and kind of grasp were found also when names instead of images of objects are presented (Tucker and Ellis 2004).Borghi, Glenberg and Kaschak (2004) found with a part verification task that responding by pressing a button in a direction compatible with the part location (e.g. responding upward to verify that the name 'head' designates a part of a horse) was faster than responding in a direction incompatible with the part location. There is also evidence that the semantic meaning of words affects the grasping and reaching kinematics (Gentilucci 2003). The meaning of words as "large" or "small" had an effect on the grip aperture in the initial grasp kinematics (Gentilucci and Gangitano 1998; Glover and Dixon 2002). Overall, these studies prove that the semantic meaning of words affects the motor system. However, the tasks used always required either a motor preparation or a specific activation of the motor system – for example participants had to prepare a specific motor response or had to perform a reaching or a grasping behavior to answer. Let us make an example of what we mean by "motor preparation" preceding the experiment. Klatzky, Pellegrino, McCloskey, and Doherty (1989) assessed whether priming a hand shape facilitated judging whether actions performed with objects were sensible. They found compatibility effects between different hand 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 were submitted a phase of "motor preparation", i.e. they learned to associate the prime, which could be presented either visually or verbally, to a specific gesture they had to perform. Whereas some experiments are preceded by a motor preparation, other imply a "specific activation of the motor system", i.e. the responses required involve the same kind of motor actions the stimulus is supposed to elicit. As an example of what we intend with "specific activation" of the motor system consider the study by Tucker and Ellis (2004) who found a compatibility effect between the size of object referred to by names and the kind of motor response required by the task. In their experiment object size was not relevant to the task, which consisted of deciding whether the objects were artifacts or natural kinds, but the motor action used to provide the response (a kind of grasping response that mimicked either grasping objects with a precision or with a power grip) is the same we use while grasping objects. Consider, instead, classic RTs experiments in which the motor response consists simply of pressing a button on the computer keyboard. If we provide evidence of activation of motor information also in the last case, this would show that object concepts directly incorporate information on how to manipulate them, and that this information is immediately accessible to be used for acting.

The first aim of the present study is to verify whether object manipulability influences response times in a categorization task that does not require pre-activation of the motor system. As discussed later, finding an effect of manipulability in a categorization task would be very relevant to embodied theories of cognition, according to which concepts are grounded in sensorimotor experiences with their referents. The second aim of this study is to assess whether the activation of motor-related information differs depending on how the visual input is presented, i.e. as a word or as a drawing. 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 in explaining it. In fact, similar results obtained in the same task with pictures and words, demonstrating that motor information is activated by both pictures and words, cannot be explained solely on the basis of the activation of a direct vision-to-action route. Rather, they would demonstrate that conceptual knowledge is accessed, and that the ventral system is probably involved.

Further, we aim to disambiguate the effects of action and function. For this reason we used manipulable and non-manipulable artifacts and natural objects. Further, in Experiment 1 we asked participants to categorize objects into natural or artefacts, in Experiment 2 we made manipulability relevant to the task by asking participants whether the objects could be put inside a backpack or not. With artifacts we predict an interference between functional information and the motor program necessary to accomplish the task in both experiments. We also predict that the activation of action information leads to an interference for manipulable objects in Experiment 1 and to a facilitation in Experiment 2, when manipulability was relevant to the task.

Experiment 1

If object concepts automatically activate action ("how") information, this information could affect the motor program necessary to accomplish the task leading to process differently to manipulable and non-manipulable objects, and to respond differently to manipulable objects with the dominant hand than with the other one. Indeed, prehension movement are more associated with the more skilled dominant hand (see also Handy, Grafton, Shroff, Ketay, and Gazzaniga 2003).

Concepts referring to artifacts surely contain more functional attributes than natural objects, therefore it can be assumed that the activation of function interferes more with artifacts than with natural kinds.

Method

Participants and design. Twenty-two right-handed students of the University of Bologna took part in the experiment. They either volunteered their participation or received course credit for their time.

Materials. Sixty-four items controlled for familiarity, number of syllables, word frequency, visual complexity were selected from the Lotto, Dall'Acqua and Job (2001) database of Italian words and black-and-white drawings of common objects. A pre-test was performed in order to select, from the original set of 64 items, clearly manipulable and clearly non-manipulable items. 12 participants were presented with one word at a time and had to decide whether the object it referred to was manipulable or not. In this way 40 items were selected: 10 manipulable artifacts (knife), 10 manipulable natural objects (carrot), 10 non-manipulable artifacts (boat) and 10 non-manipulable natural objects (palm). While selecting the items we made sure that within each group of items (manipulable natural kinds, non-manipulable natural kinds, manipulable artifacts, non-manipulable artifacts) there were members of different categories. Within each group there were items of at least 3 categories, and there were at least 2 members of each category. For example, non-manipulable artifacts included 3 members of the category "vehicle", 5 of the category "building", and 2 of the category "furniture".Even though the items in each condition were not many, this does not prevent the generalization of the results, as the selected items were quite typical everyday concepts of different categories, among the most frequently studied in the literature. Each of the selected items was presented 4 times, in 2 different modalities: as a word and as a drawing. The pictorial stimuli were presented centrally on the screen. The left-right orientation of the pictorial stimuli with a protruding part (e.g. hammer) on the screen was balanced.

Procedure. Participants sat in front of a computer monitor. Each trial began with a fixation point (+) displayed for 1000 ms. Immediately after the fixation point disappeared, depending on the experimental block either a word or a picture appeared, remaining on the screen until the participant's response. Participants had to decide whether the presented word or picture referred to an artifact (e.g. knife) or to a natural object (e.g. palm). Half of them pressed the right button in response to artifacts and the left button in response to natural objects. The other half had the opposite mapping. Participants received feedback on reaction time (RT) after pressing the right key (the reaction times were displayed), as well as after pressing the wrong key ("ERROR") or after taking 3000 ms to respond ("You have not answered"). The next trial began after the feedback disappeared. The experiment consisted of 2 practice blocks of 24 practice trials each and of 2 experimental blocks, one for words and one for drawings. The presentation order of the experimental blocks varied for each participant. In each experimental block the 40 critical trials were presented twice, in a different random order for each participant. After each block, participants could take a brief break. Overall the experiment lasted about 20 minutes.

Data analysis and results

RTs more than 2 standard deviations from each participant's means were excluded from the analysis. Correct RTs were entered into two mixed ANOVAs, one on the participants' data and one on the materials. In the ANOVA with participants as random factor Kind of Concept (artifact, natural kind), Manipulability (manipulable, non-manipulable objects) and Presentation Mode (drawing, word) were manipulated within participants, while Mapping (artifact-left hand/natural-right hand vs. the opposite) was manipulated between-participants. In the ANOVA with materials as random factor, Kind of concept and Manipulability were between materials factors, whereas Presentation Mode and Response Hand (right, left) were within materials factors.

The two main effects of Kind of Concept and Presentation Mode were significant both in the analysis on participants (indicated by F^1) and on materials (indicated by F^2) (respectively F^1 (1, 20) = 17.39, *MSe* = 1283.4, $p < .001$; F^2 (1, 36) = 6.19, *MSe* = 2439.5, $p < .05$; F^1 (1, 20) = 4.17, *MSe* = 2063.8, $p < .0001$; F^2 (1, 36) = 625.45, *MSe* = 765.7, $p < .0001$). Responses to natural kinds were, on average, 23 ms faster than responses to artifacts, and drawings were elaborated 109 ms faster than words. The interaction between Kind of Concept and Presentation Mode, F^1 (1, 20) = 5.06, *MSe* = 513.2, $p < .05$, was significant due to the fact that with artifacts pictures were elaborated 30 ms faster than words, whereas with natural objects the difference between pictures and words was reduced to 15 ms.

The 3-way interaction between Kind of Concept, Manipulability and Presentation Mode was also significant, F^1 (1, 20) = 5.18, *MSe* = 476.1, $p < .05$; F^2 (1, 36) = 9.71, *MSe* = 765.7, $p < .01$. As it can be seen in Figure 1, pictures were processed always faster than words and natural kinds always produced faster responses than artifacts. The only exception were natural manipulable pictures, which were slower than natural non-manipulable pictures (Newman-Keuls, F^1 $p < .06$; F^2 $p < .05$), and did not differ from pictures of both manipulable and non-manipulable artifacts.

Insert Figure 1 about here

In the analysis on materials Kind of Concept and Hand of Response interacted, F^2 (1, 36) = 12.79, $p < .01$, due to the fact that responses to natural kinds with the right hand were the fastest (Newman-Keuls, $p < .001$). However, a closer look at the data showed that this was mainly due to not-manipulable objects.

Discussion

The results suggest that both action and function information are activated. The finding that pictures of manipulable natural kinds were responded slower than pictures of non-manipulable ones may be due to the fact that the activated action information causes an interference with the motor program necessary to accomplish the task. Even if the motor program was a simple key press and the required motor response was not the one we typically use for interacting with objects, object processing activated the motor system. This interpretation is supported by the similarity between our results and those by Gerlach et al (2002). They found that specific neural areas were activated with manipulable objects; crucially, in response times this activation corresponded to a disadvantage in processing manipulable fruit and vegetables compared with non-manipulable animals. The advantage of natural kinds over artifacts, given that it was not due to word frequency, familiarity, and visual complexity, may depend on an interference between the functional information artifacts elicited and the motor program necessary to accomplish the task. This interference effect was weaker with pictures than with words. This is compatible with studies showing that pictures activate affordances more directly than words.

However, another possible explanation of the result may be advanced. Compared to artifacts, natural kinds have a higher degree of within category similarity. In the literature, it has been proposed that tasks requiring separate responses to individual category members, such as naming, are negatively affected by perceptual similarity, whereas tasks requiring common responses to different members, such as categorization, are positively affected by perceptual similarity (Humphreys, Riddoch and Forde 2002). According to this explanation, natural kinds, being perceptually more similar than artifacts, should be processed faster than artifacts in a categorization task.

Experiment 2

In Experiment 2 participants were asked to categorize items based on whether it was possible or not to pick them up and put them inside a backpack. This task aimed to increase the relevance of manipulability, but again without activating the motor system for response production. It should be noted that in this way only the role of manipulability, but not of function, was made more relevant. Accordingly, we predict no interference but a facilitation of manipulable objects over non-manipulable ones. Moreover, given that with natural objects action and function information correspond, responses to manipulable natural kinds should be faster than responses to manipulable artifacts.

As to function information, there should be again an interference of function information occurring with artifacts. If the advantage of natural kinds over artifacts is replicated, the explanation according to which the difference depends on within category similarity can be ruled out.

Method

Participants. Twenty right-handed students of the University of Bologna volunteered their participation.

Materials. The materials were the same as those in Experiment 1.

Procedure. The same procedure was used as in Experiment 1, but now participants were shown an open backpack and were asked to press a different key to decide whether the object could be picked up and put inside the backpack (e.g., knife) or not (e.g., palm).

Data analysis and results

As in the previous experiment, RTs more than 2 standard deviations from each participant's means were excluded from the analysis. Correct RTs were entered into two mixed ANOVAs, one on the participants' data and one on the materials, as in Experiment 1. In F^1 Kind of Concept, Manipulability and Presentation Mode were manipulated within participants, whereas Mapping (manipulable-left hand response key/non-manipulable-right hand response key vs. the opposite) was manipulated between-participants. In F^2, Kind of concept and Manipulability were between materials factors, whereas Presentation Mode and Response Hand were within materials factors.

Natural objects were responded 11 ms faster than artifacts, F^1 (1, 18) = 5.54, *MSe* = 843.6, $p < .05$, and drawings were processed 112 ms faster than words, F^1 (1, 18) = 77.5, *MSe* = 6520.1, $p < .0001$; F^2 (1, 36) = 454.82, *MSe* = 1115.4, $p < .0001$. However, the interaction between Kind of Concept and Presentation Mode, F^1 (1, 18) = 5.68, *MSe* = 520, $p < .05$, showed that the difference between artifacts and natural kinds was mainly due to the fact that with words artifacts were processed 19 ms slower than natural kinds, whereas with pictures RTs did not differ with artifacts and natural kinds (respectively ms 585, ms 583)

Crucially, Kind of Concept and Manipulability interacted due to the fact that manipulable natural kinds were the fastest to be processed, F^1 (1, 18) = 6.51, *MSe* = 1150.3, $p < .05$, F^2 (1, 36) = 3.28, *MSe* = 1115.4, $p < .08$.

The 3-way interaction between Kind of Concept, Manipulability, and Presentation Mode, F^1 (1, 18) = 12.63, *MSe* = 531, $p < .01$; F^2 (1, 36) = 7.33, *MSe* = 1115.4, $p < .01$, showed that manipulable natural kinds words were the fastest to be processed among words (Newman-Keuls, $p < .01$), even though pictures were always processed faster than words ($p < .001$) (see Figure 2). Interestingly, pictures of manipulable artifacts were processed faster than pictures of non-manipulable ones, and responses to pictures of manipulable natural objects were faster than those to pictures of non-manipulable ones. However, these differences did not reach significance in the pairwise comparison.

Insert Figure 2 about here

In the analysis on materials the 3-way interaction between Kind of Concept, Presentation Mode and Hand of Response, F^2 (1, 36) = 6.65, *MSe* = 494.6, $p < .014$ was significant (see Figure 3). Post-hoc Newman-Keuls showed that right hand responses to manipulable natural kinds were significantly faster than all other responses ($p < .02$) but to left hand responses to manipulable natural kinds; the latter were faster than non-manipulable right hand responses ($p < .01$) and faster than responses to non-manipulable artifacts, but the differences did not reach significance ($p < .07$; $p < .09$). Thus with natural kinds, but not with artifacts, there was a clear advantage of manipulable objects, particularly when they were responded to with the right hand.

Insert Figure 3 about here

Discussion

The most significant results were the effect of manipulability and the advantage of natural kinds over artifacts. The effect of manipulability, which was restricted to natural objects, was complemented by the advantage of right hand responses with manipulable natural kinds. The advantage of the right hand with manipulable objects is in line with PET studies showing that imagined right hand movement activate the same area of the brain as manipulable tools (Grafton, Arbib, Fadiga and Rizzolatti 1996). Therefore, it suggests that object names retrieved the right-hand movements associated with them. Consistently with this, Wohlschläger and Bekkering (2003) showed that children prefer to use the dominant hand when imitating the grasping of objects, while no such hand preference is observed when they imitated pointing towards objects.

The facilitation for manipulable natural kinds and not for artifacts is probably due to the fact that the first represent a case in which action and function information overlap. This is not true for manipulable artifacts, for which extracting function may have slowed down response times. The advantage of natural kinds over artifacts suggests that automatic activation of function slowed down RTs with artifacts. The interference of function took place with words, not with pictures, possibly because pictures activate function more directly than words. As the task was not to categorize objects into natural or artifacts, it is very unlikely that participants accessed the category before providing an answer, thus the explanation according to which the advantage of natural kinds over artifacts is due to the higher within-category similarity of the former can be ruled out.

General discussion

The present study aimed to investigate whether object concepts conveyed either by drawing or by words automatically activated motor information on how to interact with objects. If that were the case, automatic activation of such information should have an effect on the response times even when task performed did not imply a motor preparation or a specific activation of the motor system.In Experiment 1 the automatic activation of action information lead to longer RTs while processing pictures of manipulable compared to pictures of non-manipulable natural objects. This interference effect disappeared in Experiment 2, when manipulability was made relevant for the task: the activation of action information facilitated responses to manipulable natural kinds and right hand responses to manipulable natural kinds. This suggests that participants might imagine grasping the objects with their dominant hand. This occurred with manipulable natural kinds and not with manipulable artifacts, likely as with manipulable natural kinds action and function information overlap. The results suggest that both action and function information are automatically activated in decision tasks. When this information was not relevant to the task, its activation leads to interfere with the motor program necessary to accomplish it.

In both experiments the processing disadvantage of artifacts over natural kinds clearly suggests that function information is automatically activated, leading to interference with the motor program necessary to accomplish the task.

As to the relationships between Presentation Mode and Manipulability, the similarity of the result pattern obtained with words and pictures allowed to argue that also words activate action information. In fact we found no interaction between Manipulability and Presentation Mode and manipulable words referring to natural kinds were processed faster than all other words. The striking similarity of the results obtained with drawings 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, i.e. by the ventral system.

A last point is worth of note. When manipulability was relevant for the task, the advantage of natural kinds over artifacts clearly emerged with words. This raises the possibility that words interfere with processing when functional information has to be extracted. This is consistent with preliminary evidence by Bub et al. (2003) who found that naming was not affected by function but that affordances driven by object shape, rather than functional knowledge, are involved in object naming.

Conclusion and implication for cognitive science

The results suggest that seeing pictures and processing words referring to manipulable objects activates the motor system. The effect found also with words argues for the involvement not only of the dorsal but also of the ventral system and of long-term visuomotor associations between objects and actions in generating affordances. This is consistent with evidence showing that to perform gestures appropriate to objects it is necessary to combine conceptual knowledge with affordances derived from objects (Creem and Proffitt 2001; Buxbaum, Sirigu, Schwartz, and Klatzky 2003).

More generally, our results support theories claiming for a strict interaction between language, concepts, and the motor system. Namely, the finding that both drawings and words referring to objects activate information on manipulability is consistent with the so-called "embodied" theories of cognition. Embodied views oppose to standard cognitivist theories according to which the mind is a symbols manipulation device and concepts are given by abstract, amodal and arbitrary symbols (Pylyshyn 1986; Fodor 1987; for more recent formulations see Landauer and Dumais 1997). In the last years much evidence has been collected showing that, in antithesis with theories that posit perception and action as separate spheres (Pylyshyn 1999; Sternberg 1969), perception and action are strictly interwoven (Berthoz 1997). In addition, as mentioned before, recent studies have provided evidence of the tight interrelations between conceptual organization, language and the motor system: more specifically, it has been shown that language recruits the same systems used for perception and action. According to embodied views, concepts are grounded in sensorimotor processes (Barsalou 1999; Gallese and Lakoff 2005; Glenberg 1997). More specifically, they are recordings of the neural activation that arises during perception and action arranged as distributed systems or "simulators" (Barsalou 1999). Thus, conceptual information is distributed over modality specific domains (visual, tactile, auditory, etc.) (Boronat, Buxbaum, Coslett, Tang, Saffran, Kimberg, and Detre 2005; Martin, Wiggs, Ungerleider, and Haxby 1996), and the activation of the specific modalities depends on their relevance during knowledge acquisition and for the current situation (Pecher, Zeelenberger and Barsalou 2003) The difference we found between manipulable artifacts and natural kind is perfectly accounted for by the view that information is distributed over modality specific domains:

namely, with artifacts both action and function are activated, whereas for natural kinds either function information is not activated, or action and function coincide, as for example while picking up vs. eating a cherry.

Proponents of a standard cognitivist approach might argue that a theory conceiving of concepts as arbitrary symbols might be able to account for our data. However, there are several reasons why we believe that an embodied explanation is the more appropriate one. First of all, differently from embodied theories, cognitivist theories might eventually provide post-hoc explanation for our results, but would hardly predict them. Further, our behavioral data are perfectly in line with results of neuroscience. Finally, the reliance of standard theories on pre-stored knowledge would lead to a problem of combinatorial explosion. Consider the different effects of Manipulability we found in Experiment 1 and 2: there are so many different actions and so many potential contexts in regard to both manipulable and not manipulable objects that it would be very difficult to have encoded all of the different action and context links, as well as all the procedures to activate depending on the selected action and context. Amodal views have no principled way to account for the flexibility and contextual sensitivity of our cognitive system. The last, more general reason why we believe that embodied accounts are more convincing than standard ones is that to our knowledge no clear empirical support for amodal symbols has been provided so far (see Barsalou 1999, and Barsalou, Simmons, Barbey, and Wilson 2003, for a similar argument). For all these reasons we believe that embodied theories provide more simple and convincing explanation of our data, and that they represent a most fruitful and promising approach in cognitive science. Clearly, many outstanding issues remain concerning how action information is activated by object concepts. This chapter represents only a step trying to show that object concepts automatically activate information on how to grasp and manipulate them. The automatic activation of manipulability information allow to respond quickly and efficiently to objects in our environment. At the same time, as the differences between the two experiments indicates, our cognitive system is highly flexible and perfectly able to activate different manipulability information depending on the context. More detailed empirical evidence is required in order to verify whether, besides general information distinguishing manipulable and not manipulable objects, seeing objects and hearing or reading their name lead to automatically activate specific motor programs in order to interact properly with objects.

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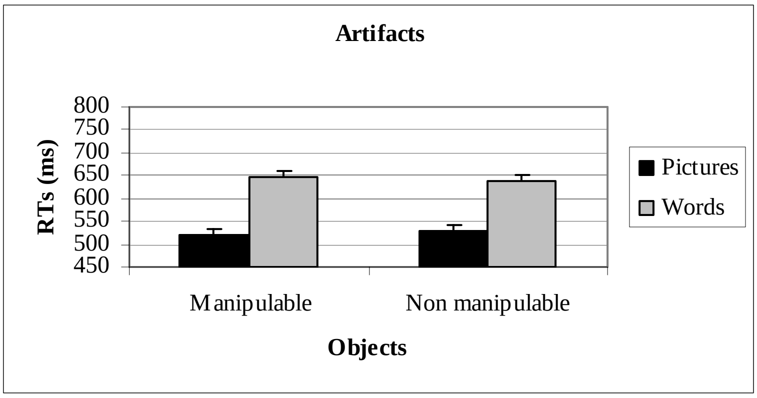
Figure captions

Figure 1. Experiment 1. 3-way interaction between Manipulability, Kind of Concept and Presentation Mode.

Figure 2. Experiment 2. 3-way interaction between Manipulability, Kind of Concept and Presentation Mode.

Figure 3. Experiment 2. 3-way interaction between Manipulability, Kind of Concept and Response Hand.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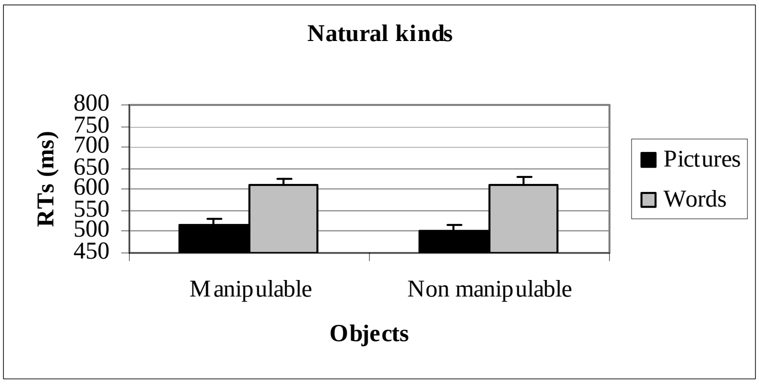
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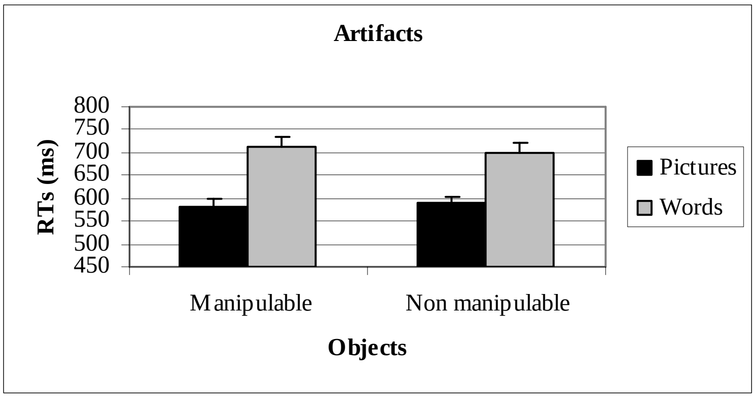
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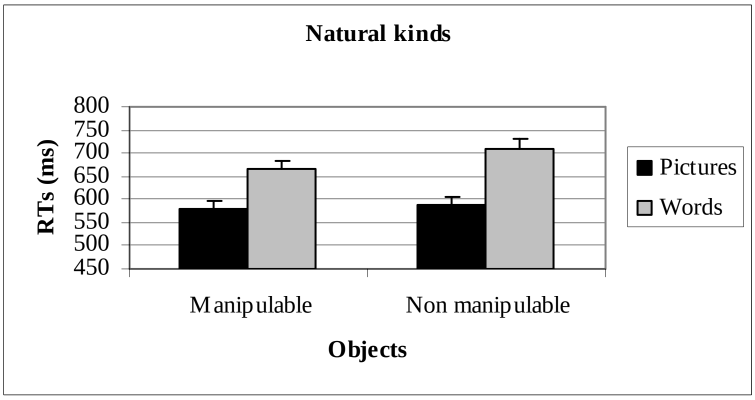
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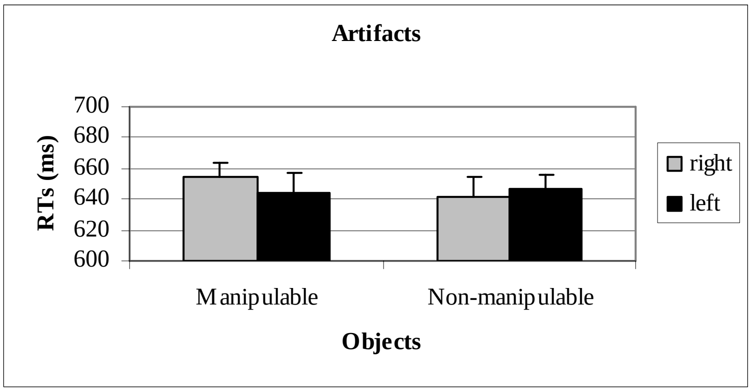
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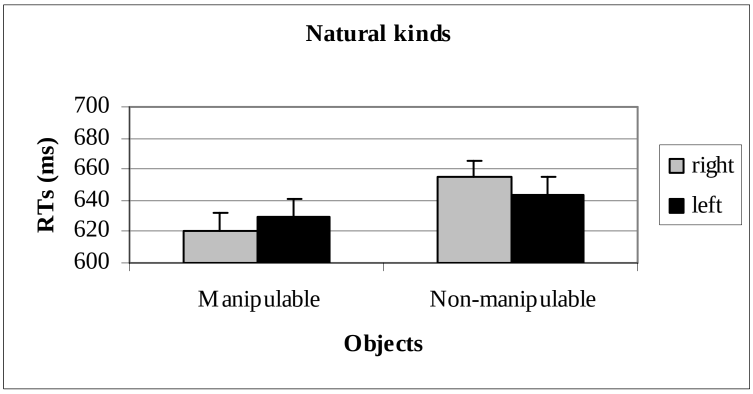
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