Is a small apple more like an apple or more like a cherry? A study with real and modified sized objects.

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Abstract

In a categorization experiment we assessed whether seeing objects automatically activates information on how to manipulate them. The experiment also aims at investigating the role played in a categorization task by online, visual information (i.e., of information mediated by the dorsal system), and by information stored in memory (i.e., information mediated by the ventral system). Participants categorized photographs of objects manipulable either with a power or a precision grip into artifacts or natural kinds. Target-objects were preceded by primes consisting of photographs of hands in either grasping postures (precision or power grip) or in a neutral posture (grip). Target-objects could be presented either in their real size or in modified size, so that they activated a different kind of grip. For example, a strawberry was presented both in its real size and with the size of an apple, so that it activated a power grip. Results confirm that visual stimuli activate motor information. More importantly, they suggest a crucial role of online, visual information even in a categorization task. Results are discussed in the framework of theories on the role of online and offline memory features.

Introduction

In the last years many studies have highlighted the importance of action for knowledge. Recent evidence has shown that manipulable objects directly activate motor information. Neuroimaging studies have shown that specific brain areas are activated for manipulable compared to non manipulable objects. 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 & 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 difference between artifacts and natural kinds, but it is probably due to the fact that tools are manipulable objects. This is confirmed by a PET study by Gerlach, Law and Paulson, (2002) who showed in a categorization task that 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. In line with these results, Kellenbach, Brett and Patterson (2003) found that the response of the left ventral premotor cortex and the left middle temporal gyrus was stronger for manipulable than for non-manipulable objects in action judgements, whereas no specific cortical region was more activated by function relative to action judgements.

On the behavioral side, different studies have demonstrated the close relationships between perceptual and motor information. 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 – more specifically, information related to reaching and grasping movements. Ellis and Tucker (2001) asked participants to categorize objects graspable either with a precision or with a power grip into artifacts or natural kinds by pressing a device. Participants responded faster to object graspable with a power grip by mimicking a power grip, and to objects graspable with a precision grip by mimicking a precision grip. Thus they found a compatibility effect between the object size and the grip used to respond, even if the object size was not relevant to the task. Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi and Nicoletti (2006) asked participants to categorize photographs of objects graspable with a power or a precision grip into artifacts or natural kinds. Target objects were preceded by a prime consisting of photographs of hands in either grasping posture (precision or power grip) or in a neutral posture (open hand). Participants were required to decide, by pressing a different key, whether the target objects were artefacts or natural kinds. Borghi et al. (2006) found a compatibility effect between the hand posture (power, precision) and the kind of grip required by the object, provided that the experiment was preceded by a motor training phase in which participants repeated the postures they saw in the photographs. This study showed that visual hand stimuli activate a motor resonance phenomenon and that seeing objects evokes a specific motor program also in absence of a motor response relevant to the task. Namely, participants simply had to press a different key in order to categorize objects.

The reported studies on prehension clearly suggest that visual stimuli activate motor information, both when the object size is not relevant to the task (Ellis & Tucker, 2000 and Borghi et al. 2006) and when the motor response is not relevant to the task. Moreover, the study by Borghi et al. (2006) suggests that seeing hand postures and using the body to reproduce the seen postures might induce a motor resonance behavior, mediated by the mirror neuron system (Di Pellegrino et al., 1992). This motor resonance explains the prime-target compatibility effect.

However, these studies providing evidence for compatibility effects leave a question open. Namely, it is unclear whether the compatibility effect are due to the processing of online, visual information, or if they are due to the influence of conceptual information stored in long term memory. In order to explain the relationships between vision and action, an influential model (Milner & Goodale, 1995) proposes that visual information is processed in the brain in two different streams: the ventral and the dorsal route. Whereas the main role of the ventral stream pertains object recognition, the dorsal stream has primarily a pragmatic role. Accordingly, there would be two different routes to action: one mediated by object recognition (ventral stream), the other one implying a direct vision-action mapping (dorsal stream) (Rumiati & Humphreys, 1998). However, recent evidence suggests that the distinction implied by this model between an “acting” and a “knowing” brain might be too sharp (see for a first comment Gallese, Craighero, Fadiga & Fogassi, 1999) and that different kinds of action-related information might be subserved by different neural pathways (Gentilucci, 2003).

Aim of our study was to assess whether the compatibility effect found are due to online information or to information related to past visuomotor experiences stored in memory. We used a paradigm similar to the one used by Borghi et al. (2006), with some slight variations and a more important variation. We presented three hand primes, two prehensile postures (precision, power) and a catch-trial (fist). Compared to the study by Borghi et al. (2006), we used more dynamical primes, so that they could more directly elicit motor information even without a motor preparation phase. As in the previous study, the hand primes were followed by target-objects, half artefacts and half natural kinds. All objects were manipulable, half were graspable with a power grip (e.g., apple), and half with a precision grip (e.g., strawberry). The most important variation we introduced consisted of the fact that the targets could represent objects either in their real size or in a modified size. Thus, the objects typically affording a precision grip were zoomed out (for example a nut was enlarged to an orange size) and the object usually affording a power grasp were zoomed in (for example an apple was resized to became as small as a cherry). In this way we were able to disentangle the contribution played by online, visual information, and the contribution of off-line information stored in memory, in explaining the effects.

The main predictions of our work are the following. First, we predict to replicate with different stimuli the results found by Borghi et al (2006). Thus, we predict a processing advantage of natural kind objects over artefacts, as the first activate only action and the latter both action and functional information. In addition, if seeing an object activate motor information, we predict an advantage of objects graspable with a power grip in their real size (e.g., of apples and tins over strawberries and rubbers, independent of whether apples and tins were presented in their real or modified dimensions) over objects graspable with a precision grip. This should happen because, in real life, the power grip is less complex than the precision grip. The crucial prediction, however, concerns the role played by online and offline information. If the role of online visual information overcomes that the information stored in memory, then we should find an interaction between the object size (real, modified) and the grip the object typically elicits (power, precision). More specifically, if online information is more important than information stored in memory, then there should be a different response pattern when the object size is the same as the typical one (for example, when an apple is presented in its standard size) as well as when it is modified (for example, when an apple is presented with the same size as a cherry). Namely, with modified size objects participants should respond on the basis of what they SEE (i.e., on the basis of the modified object size) rather than of what they KNOW (i.e. of the real object size). On the contrary, if memory information plays a more important role than online visual information, then we should find the same effect with real and modified size objects.

Finally, if the compatibility effects found in previous studies (Ellis & Tucker, 2001; Borghi et al., 2006) depend on online information, then we should find a compatibility effect between the prime and the target presented in its modified dimension. Otherwise, if long term visuomotor memories are responsible of the effect, then faster responses should be expected in case of compatibility between the postures of the hand primes and the real dimension of the objects.

Method

Participants

Twenty students (12 women and 8 men) of the Department of Communication Sciences of Bologna's University took part in the experiment. All were right handed, they all had normal or corrected to normal vision and they don't receive any payment or credits for the time spent doing this experiment.

Materials and design

The stimulus set was made of coloured digital photos of a human hand displaying one of three different postures (precision, power, or fist) (see fig. 1) and by 24 pictures showing a common object closed to a 50cent coin (see fig. 2, as example). Then a new set of photos was created using the previous set of 24 pictures and manipulating them with Acrobat Photoshop program in order to modify the objects' size. The objects normally affording a precision grip were zoomed out, between 7 and 10 cm height (for example the nut was enlarged to the orange size) and the object usually affording a power grasp were zoomed in, approximately 2 cm height (for example the apple was resized to became small as a cherry). The 50cent coin size was the same in each picture. The presence of the coin allowed to understand whether the objects was presented in its real or modified size. A special care was taken in selecting everyday and common objects.

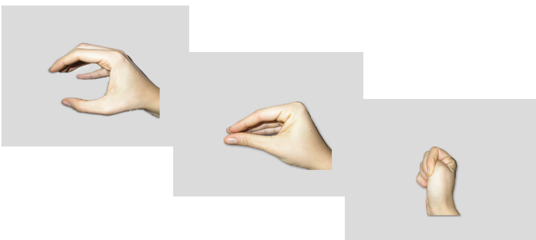

Figure 1: The three hand primes. The first two primes display a precision and a power grip. The third prime, that worked as a catch-trial, displays a fist. Both left and right hand primes were presented.

Twelve of the objects were natural (fruit, vegetables, flowers or animals) and the other twelve were man-made (tools or utensils). Within each category half of the objects required a precision grip and half a power grip. Each slide was presented two times with the objects in their real size and two times with the objects in their modified size.

Procedure

Participant 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. In half of the trials, the hand on the screen was a right hand and in half of the trials, it was a left hand. The prime was followed after 250 ms by the target consisting of the picture of an object (e.g., a tin, an orange) closed to the 50cent coin. The sequence is showed in fig. 3. All stimuli were displayed centrally on the monitor ad randomised. When the prime was a hand mimicking a precision or a power grip, half of the participants were required to make a right-hand key press response if the target object was natural and a left-hand key press response if it was an artefact. Half were randomly assigned to the opposite hand-to-category arrangement. When the prime was a fist (catch trial), participants had to refrain from responding to the target and had to wait for the next trial. The target object was displayed on the screen for 2000 ms or until the participant responded. All participants were informed that their response times would be recorded and invited to respond as quickly as possible while still maintaining accuracy.

Figure 2: An example of the stimuli: an artefact (tin) graspable with a power grip in its real and modified size and a natural object (strawberry) graspable with a precision grip in its real and modified size.

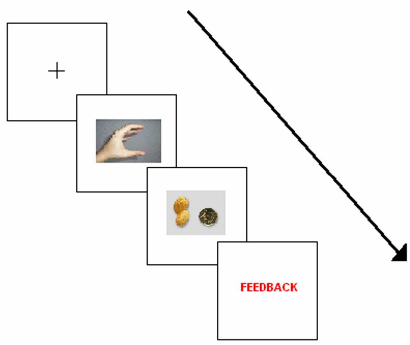

Figure 3: The experimental sequence.

Results

3,5% of the trials were removed as errors. Reaction times (RTs) more or less than 2 standard deviations from each participant's mean, as well as RTs for incorrect responses, were excluded from this analysis. This trimming method lead to remove 2% of the data. The mean RTs for correct response for each participant were submitted to a repeated measures 2x2x2x2 ANOVA with the within subjects factors of Object Kind (artefact, natural object), Grip (precision, power), Hand Prime (precision, power), and Object Size (real, modified). Two participants were eliminated as they made more than 14% of errors. Given that the analysis on errors (excluding time-outs and errors with the catch-trials) revealed that there was no evidence of a speed accuracy trade-off, we focused on the RT analysis.

Among the main effects, the Grip was significant due to the fact that, as predicted, objects graspable with a power grip (e.g., orange, tin) were processed faster than objects graspable with a precision grip (e.g., strawberry, match), F (1,17) = 4.7, MSe = 1208.22, p <.045. Also the difference between artefacts and natural kinds was marginally significant, F (1,17) = 4.25, MSe = 2130,26 p <.055, due to the advantage of natural kinds over artefacts, probably caused by the activation of functional information with the latter.

The most important result was the interaction between and Object Size and Grip, F (1,17) = 22.36, MSe = 823.49, p < .001. Newman-Keuls post-hoc analyses showed that this was due to the fact that, whereas real size objects graspable with a power grip were processed faster than real size objects graspable with a precision grip (e.g., apples were processed faster than nuts), this was not the case for objects presented in their modified size. Namely, with modified size objects the pattern was reversed, as the objects typically graspable with a precision grip but presented with enlarged dimensions (e.g., a nut as large as an apple) were processed faster than objects graspable with a power grip presented with reduced size (e.g., an apple as large as a nut). However, the last difference did not reach significance (see Fig, 4).

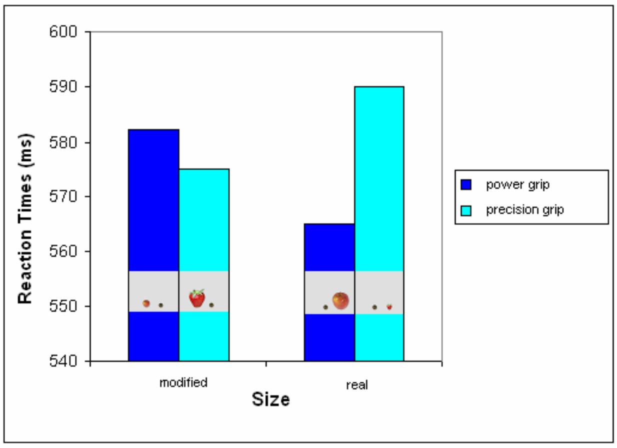

Figure 4: Interaction between Object Size and Grip.

The result suggests an important role played by online, visual information, and thus of the dorsal system, even in a task, a categorization one, in which the ventral system is necessary involved. As it can be in the figure (see Fig 5), the pattern we found is much more similar to the pattern that could be elicited by the activation of online information (dorsal system) than to the pattern that could be elicited by the activation of offline memory features (ventral system). Namely, if results depended only on online information, then objects larger in size should be processed faster than small objects, independently from their original size. For example, the results should be the same for large strawberries as well as for standard apples.

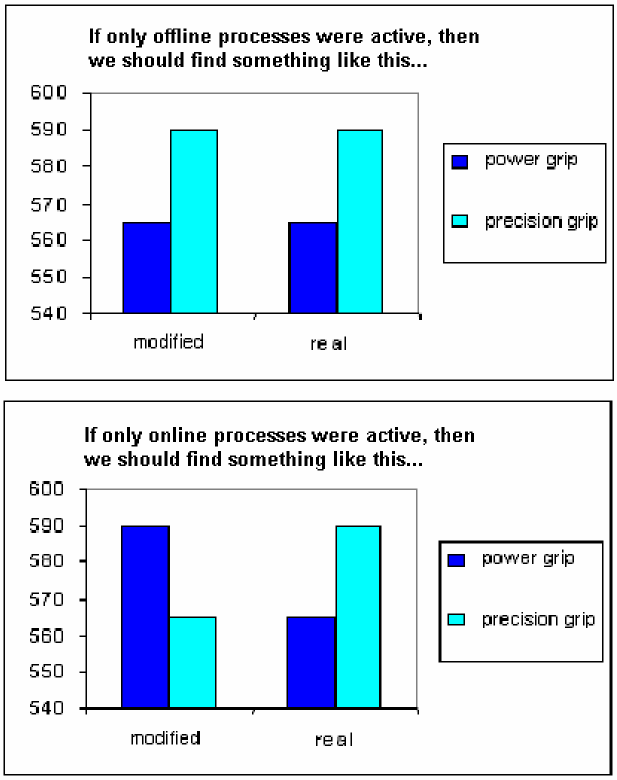

Figure 5: Possible results.

On the contrary, if results depended only on information in memory, then we should find that responses to objects in their real and modified dimension do not vary (Figure 5b).
We also found a significant interaction between the Prime, the Kind of Object and the Object size, F (1,17) = 4.34, MSe = 468.03, p <.053, (see Fig 6).

Newman-Keuls post-hoc analyses showed that this was due to the fact that for real size objects artefacts preceded by a power grip were slower than natural kinds preceded by both power and precision grip (593 vs. 565 and 571ms). This interaction suggests that visual hand primes have an influence on real size but not on modified size objects. The faster RTs obtained with the precision compared with the power prime, confirm that artefacts evoke functional information, as the precision posture is typically more linked to fine prehension, and thus to function.

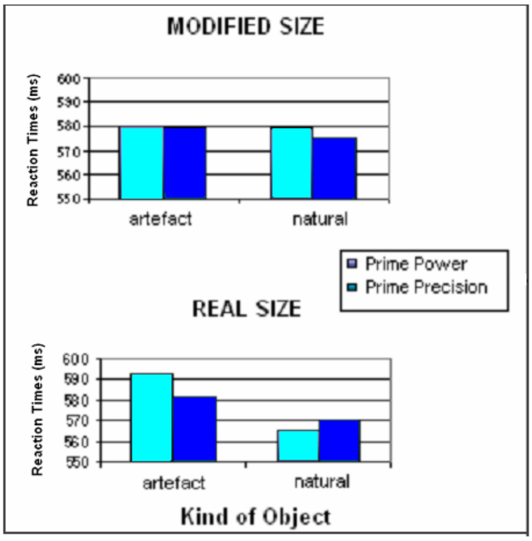

Figure 6: Interaction between Object Size and Grip.

Discussion

Our results clearly confirm previous studies showing that visual stimuli activate motor information. More importantly, this study suggests an important role of the online information also in a categorization task.

The advantage of objects typically graspable with a power grip over objects graspable with a precision grip suggests that visual stimuli automatically activate motor information and lead to internally "simulate" a grasping action. Namely, the longer RTs with the precision grip is due to the fact that, in real life, grasping an object with a precision grip is more complex than grasping an object with a power grip (Ehrsson, Fagergren, Jonsson, Westling, Johansson, Forssberg, 2000). The difference between artefacts and natural kinds can be explained by the fact that the first evoke both action and functional information, while the second activate only action information (Warrington & Shallice, 1984). The activation of functional information with artefacts might have lead to the longer processing times with the latter.

The most important result, however, concerns the role of online and offline memory features in explaining the effects. Even though a categorization task was used, the role of on-line information, mediated by the dorsal system, was clearly very relevant, as shown by the interaction between Grip and Object Size. The results indicate that categorization is mainly based on online processed information. This suggests a major role of the dorsal system in explaining our results. This is particularly striking as it occurs in a categorization task, that is in a task that implies the involvement of the ventral system (semantic knowledge). However, we also found that information stored in memory (off-line information) influences the recognition process. Namely, the 3-way interaction we found between Prime, Object Kind and Grip showed that the prime was effective only with objects presented in their real dimension and not with objects presented in their modified dimension. The absence of a congruency effect between the prime and the target can be due to the fact that, as in Experiment 1 by Borghi et al. (2006), no motor training phase preceded the experiment. Even though the prime stimuli were more dynamical than in the previous experiment, no motor resonance effect was triggered by the prime, thus no compatibility effect was found. However, the 3-way interaction revealed that participants were sensitive to the prime influence.

Overall, our results are in line with various recent studies that suggest that the distinction between the dorsal and the ventral stream as proposed by Milner and Goodale (1995) is probably too rigid and dichotomic (Gallese et. al. ; 1999; Derbishire, Ellis & Tucker, 2006). For example, it has been proposed that the dorsal route can be distinguished into a pure dorsal-dorsal route and a ventral-dorsal one, and that some kind of object representation is encoded in the dorsal route as well (Gentilucci, 2003). In addition, recent studies with language suggest that motor and pragmatic information is crucial for conceptual information (Barsalou et al, 2003; Glenberg, 1997; Buxbaum et al, 2003). In order to better disentangle the role played by the two systems, further experiments are planned. Namely, we aim at increasing the influence of prime on the categorization task and to verify whether we find a compatibility effect between the prime and the stimuli presented in their real or in their modified size.

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