

**On the relationship between visual imagery and visual perception:
Evidence from priming studies.**

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European Journal of Cognitive Neuroscience, 2002, 14 (2), 161-184

Abstract

Two priming experiments using a perceptual identification task were conducted to explore the functional and representational overlap between visual imagery and visual perception. The first experiment included a study phase in which primes were either perceived or imaged objects and a test phase in which targets were parts of studied and non-studied objects. Imagery primed identification when subjects were instructed to count the parts of the imaged objects in the study phase but not when they were instructed to focus on the global shape of the imaged objects. This result suggests that imagery involves perceptual representations identical to those involved in perception. It also suggests that the representational overlap between imagery and perception depends on the type of images generated, as some images may consist in global shapes only, whereas others may consist in detailed, multi-part shapes. In the second experiment, we used whole objects as target stimuli, which provided subjects with more information to identify masked targets and thereby reduced top-down processing. Priming from imagery fell beneath significance, suggesting that this sort of priming is elicited in a large part by a transfer of top-down processes from study to test.

Introduction

Imagery has given rise to numerous studies that tried to define the structural properties of the mental image. A debate began in the 70's that focused on the nature of the representations underlying imagery (Pylyshyn, 1981). The question was whether visual mental images depicted information propositionally (i.e., in a symbolic way), or analogically (i.e., in a pictorial way). Studies that focused on the relationship between visual perception and visual mental imagery provided critical data to this imagery debate. Indeed, many studies in cognitive psychology (Farah, 1988; Ishai & Sagi, 1997; Kosslyn, 1975; Shepard & Cooper, 1982), neuropsychology (Bisiach & Luzzatti, 1978; Levine, Warach, & Farah, 1985) and neuroimaging (Davidson & Schwartz, 1977; D'Esposito et al., 1997; Farah, Perronet, Gonon, & Girard, 1988; Goldenberg, Podreka, Steiner, & Willmes, 1987) converged to show that visual imagery and visual perception involve the same representations and share processes. The present study was designed to further explore the representational and functional overlap between imagery and perception.

In previous studies different methods such as mental scanning (Denis & Cocude, 1997; Kosslyn, 1973), mental rotation (Shepard & Metzler, 1988), aftereffects (Finke & Schmidt, 1977), interference effects (Segal & Fusella, 1970), vividness effects (Giusberti et al., 1992) were used to examine

the relation between perception and imagery. We took a new approach and used a priming paradigm, which allowed us to test both the similarity hypothesis and the contribution of top-down and bottom-up processes involved in both activities.

Our hypotheses bear on the model proposed by Kosslyn and Koenig (1992) that described the different functional subsystems involved in high-level vision. The authors hypothesized that many of these subsystems are involved in both imagery and perception. However, perception would principally require bottom-up processes and imagery top-down processes. According to Kosslyn and Koenig (1992), imagery starts with the activation of representations in *associative memory*. The amodal, structural description of the object to be imaged is activated, which induces subsequent activation of the perceptual, visual representations in a *pattern activation subsystem*. As a consequence, a spatial pattern of activation is projected onto a *visual buffer*. This pattern is what we will call the mental image. Generation of multi-part images engages other subsystems such as a *categorical* and a *coordinate property lookup subsystems* (both seeking representations of parts) and an *attention window* that can be moved in the visual buffer in response to *attention shifting subsystems* to each location of a first generated skeletal image that needs to be elaborated (Kosslyn, 1994).

This model predicts that imagery and perception activate identical representations, stored in a pattern activation subsystem. In

the present study we further tested this hypothesis by examining the degree to which representations involved in imagery and perception overlap in terms of the proportion of perceptual features activated.

The model also assumes that the first step of the image generation process is the construction of a skeleton of the image that can be later completed by detailed parts of the image. Independently of this sequential aspect, it is also assumed that two different types of images can be generated depending on whether the task requires the generation of global or detailed images. This is the aspect we focussed on. We hypothesized that the representational overlap between imagery and perception varies depending on the type of images generated (global versus detailed ones). As perception corresponds to a precise analysis of the stimulus during which detailed parts of the object are activated, we hypothesized that the representational overlap between imagery and perception is larger when detailed images are generated than when global images are generated.

The priming paradigm is an appropriate tool to test these hypotheses. Priming has been extensively used in the memory domain to document differences between implicit and explicit memory. Implicit memory tests differ from explicit memory tests in that they do not require subjects to recall previous episodes. Retention is made manifest in an indirect way. The speed or accuracy of the performance in a test phase is enhanced when stimuli have already been presented in a previous, study

phase. This facilitation is named priming. Two types of priming have been identified: the conceptual and the perceptual one (Cabeza & Otha, 1993; Tulving & Schacter, 1990). In the present study we focussed on perceptual priming which depends on how the target's perceptual features have been encoded in the study phase. A PET study of perceptual priming revealed changes in blood flow in area 18 of the occipital cortex for primed relative to non-primed stimuli (Squire et al., 1992). So, perceptual priming seems to occur in those areas that are engaged in the perceptual analysis of stimuli, and results from previous activation of perceptual representations. Moreover, perceptual priming is highly sensitive to the degree to which test (target) stimuli overlap with study (prime) stimuli in terms of physical features (Roediger & Blaxton, 1987a; Snodgrass & Hirshmann, 1994; Srinivas, 1993). It is also affected by the match between cognitive processes engaged in during study and test. Such an evidence has been reported by the processing theory (Blaxton, 1989; Roediger & Blaxton, 1987b; Roediger, Weldon, & Challis, 1989), which is based on studies on encoding specificity (Tulving & Thompson, 1973) and transfer appropriate processing (Morris, Bransford, & Franks, 1977). So, the more representations and processes activated in the study phase match those activated in the test phase, the more perceptual priming is enhanced.

It would follow that if mental imagery primes perception (a) the same perceptual

representations are involved in both activities; and/or (b) some processes are shared by the two activities.

Some studies report such a priming effect, essentially using verbal implicit tests (Roediger and Blaxton, 1987a, Experiment 1; Schacter & Graf, 1989, Experiment 4; Roediger, Weldon, Stadler, & Riegler, 1992, Experiment 1). Overall, these experiments revealed that generating a mental image of the written form of a word seems to activate the same representations as those activated when perceiving this word.

Surprisingly, only few studies have focussed on priming from imagery in pictorial implicit tests. McDermott and Roediger (1994) demonstrated that imaging referents of words elicited priming in a picture fragment identification test. So, imaging an object seems to activate the same visual representations as those activated when perceiving this object. In McDermott and Roediger (1994) experiments, priming from perception was greater than priming from imagery. Authors explained this result by the fact that imagery involves a weak activation of perceptual processes. In a recent study, Cabeza, Burton, Kelly, and Akamatsu (1997) obtained results suggesting that priming from imagery can be observed only if the perceptual test involves processes that match those involved in imagery. In particular, priming from imagery would occur only if the perceptual test implies top-down processing or naming. Taking these different results into account, we propose that differences in

priming elicited by imagery and by perception may result from the degree to which cognitive processes involved in the study phase match those involved in the test phase.

In the present study, we designed two priming experiments using a perceptual identification task. We systematically compared priming from imagery to priming from perception. The first set of experiments was designed (a) to examine the degree to which imagery and perception overlap in terms of the proportion of perceptual features activated, which would support the hypothesis of common representations for both activities; and (b) to test whether the representational overlap between imagery and perception varies depending on the type of images generated (global versus detailed ones). The second experiment was designed to examine whether differences in priming from imagery and perception can be explained by the degree to which processes in the study phase match those in the test phase.

Experiment 1a

In Experiment 1a we tested whether forming an image of a word's referent at study facilitates later identification of a part of the imaged object. We used a perceptual identification task composed of a study phase in which primes were either perceived or imaged objects and a test phase in which targets were parts of these objects and parts of new objects. So, study and test stimuli

were different (objects and parts of objects), which ensured that subjects did not use explicit retrieval strategies to perform the test.

Instructions in the study phase asked subjects to inspect the perceived or imaged object. Subjects had to count the number of parts of the object. We expected reliable priming when subjects imaged detailed objects parts because one of the representations activated and the representation activated in the test phase would sufficiently overlap to produce priming. However, we expected priming elicited by imagery to be less important than priming elicited by perception. Indeed, as imagery is assumed to involve top-down processes and perception essentially bottom-up processes, processing transfer (which contributes to priming) should occur in the perceptual identification task (i.e., an essentially bottom-up task) more when objects were perceived than when they were imaged in the study phase.

To examine the degree to which imagery and perception overlap in terms of the proportion of perceptual features activated, we used two types of target stimuli. Target parts could be large (low object/part size-ratio) or small (high object/part size-ratio) in comparison with the size of the whole object. For instance, eagle/beak was rated as a high size-ratio trial, whereas helicopter/propeller was rated as a low size-ratio trial. We expected large parts to overlap with the original object more than small ones and therefore, to elicit more priming. We

hypothesized the effect of the object/part size-ratio to be identical in the imagery and perception conditions, which is as expected if representations used in imagery and perception are identical.

A filler task was proposed between study and test phases. Subjects had to judge whether two pseudo-words rhymed or not. This task was supposed to prevent subjects from using an explicit strategy of recuperation of primed objects in the test phase.

Method

Subjects Thirty-two undergraduate and postgraduate students from Lyon 2 University (half female, half male, mean age 20.4 years) participated voluntarily in the experiment.

Materials and apparatus Forty concrete words divided into two lists of twenty each (list A and list B) were used in the imagery condition. They were common French words of 3 to 12 letters. Forty black and white, 8x8 cm, photographs of the objects corresponding to these words were employed in the perception condition. These photographs were divided into two lists of twenty items corresponding to the words of lists A and B.

A first pre-test was done on 14 students to determine the imagery valence of the words we used and the number of parts that can be described on imaged objects. A second pre-test was done on 14 other students to

determine the orientation at which objects were usually imaged. Our aim was to present stimuli in the perception condition that overlap with imaged objects as close as possible.

The test stimuli were constructed by extracting a part of each object of the lists A and B. All the parts were adjusted to fit within a square of 8 x 8 cm. Small parts were enlarged whereas large parts were not. In the first aforementioned pre-test, subjects had to image each proposed object, count its parts, and report these parts respecting the order in which they had counted them on the imaged object. For each object, we selected the part subjects had more often reported first. This part was usually the most perceptually salient and functionally significant part for the object identification. In addition, the part could be named easily. Half of the selected parts represented a large portion of the whole object (low object/part size-ratio) and half a small portion of the whole object (high object/part size-ratio) (see Table 1). Seven parts extracted from objects never seen or imaged in the study phase were used at the beginning of the test as training trials. We did a pre-test on 30 students to ensure that all the parts had the same level of difficulty when identified in brief and masked presentations without a prior study phase.

Twenty pairs of pseudo-words of six letters were used in the filler task. Half of the pairs were composed of pseudo-words that rhymed together and half of pseudo-words that did not rhyme together.

Stimuli were presented in the center of an Apple 14" color high resolution monitor connected to a Power Macintosh (6200/75). Brightness and contrast were maintained constant for all subjects in all conditions. A voice key from Lafayette Instruments was used in the test phase to register identification response times.

Design and procedure

Sixteen subjects participated in the perception condition and sixteen others in the imagery condition. In each condition, half of the subjects were presented with list A in the study phase, the other half with list B. Finally, four females and four males were assigned to each subgroup of eight subjects.

Subjects were tested individually in a soundproofed room. Each subject seated in front of the computer at 57 cm from the screen. Instructions were presented on the screen before the experiment began.

In the perception condition, subjects were told that the task was about visual perception. They were presented with photographs of objects and were asked to count the number of parts of each object. Each trial began with a blank screen presented for 500 ms, followed by a fixation point for 1000 ms. A second blank screen was presented for 100 ms and then, a photograph appeared for 3 seconds. A third blank screen was presented and subjects had to respond by pressing a key using their preferred hand. They pressed the numerical key

corresponding to their count. A final blank screen lasting for 1000 ms ended the trial.

In the imagery condition, subjects were told that the task was about visual mental imagery. They were presented with words in uppercase and were asked to form the visual mental image of the words' referent. Then they were asked to count the number of parts of the imaged object. Each trial was constructed as in the perception condition except that a word (instead of a photograph) appeared for 1000 ms. An empty square (8 x 8 cm) in which subjects had to form the mental image followed the presentation of the word. It disappeared when subjects responded by pressing a key using their preferred hand. They pressed the numerical key corresponding to their count.

All subjects then performed the filler task. They were told that the task was about phonological processing and had no relationship with the task they just performed. In each trial, a fixation point and a pseudo-word were presented successively and then a second fixation point and a second pseudo-word appeared. Subjects had to judge whether the two pseudo-words rhymed or not. They gave their answer by pressing either "Y" (Yes) or "N" (No).

All subjects then performed the perceptual identification task. They were told that the task was about object perception and had no relationship with the tasks they just performed. Each trial began with a blank screen presented for 500 ms, followed by a fixation point for 1000 ms. Then a

photograph of an object part appeared for 67 ms between two masks presented for 33 ms each. The mask was made of pieces of photographs mixed together. Subjects were asked to identify and name aloud as fast as possible briefly presented objects. The experimenter wrote down responses and response times were measured by means of the voice key. The test began with eleven training trials. Then, all subjects (primed either by list A or by list B) were presented with the forty parts extracted from the objects of both lists. For one subject, half of the parts were primed and the other half were not. Subjects were not told that some objects were repeated from study to test.

Results

We performed an ANOVA on the percentage of correct identifications in the perceptual identification task. Effects and interactions not reported here were not significant ($p > .05$). However, non significant interactions may be reported when they are of theoretical interest. This was a 2 (condition) x 2 (priming) x 2 (size-ratio) ANOVA, with condition (imagery, perception) as a between-subjects factor and priming (primed stimulus, non-primed stimulus) and size-ratio (high, low) as within-subjects factors.

Results showed an overall reliable priming effect, $F(1, 30) = 30.65$, $p < .01$. Subjects identified more parts extracted from studied objects ($M = 50$, $SD = 21.23$) than parts extracted from non studied objects ($M = 37.34$, $SD = 19.54$). Interestingly, the

amount of priming was not different in the perception condition (primed: $M = 45.94$, $SD = 20.92$; non-primed: $M = 31.25$, $SD = 21.36$) and in the imagery condition (primed: $M = 54.06$, $SD = 21.07$; non-primed: $M = 43.44$, $SD = 15.57$), $F(1, 30) < 1$. T-tests performed on this interaction showed that priming was significant both in the imagery condition, $t(15) = 3.68$, $p < .01$, and in the perception condition, $t(15) = 4.07$, $p < .01$. Although participants in the imagery condition seem to identify more primed and non-primed stimuli than participants in the perception condition, t-tests showed that these differences were not significant, neither for primed stimuli, $t(30) = 1.2$, nor for non-primed stimuli, $t(30) = 2.02$.

Overall the percentage of correct identifications was stronger for low size-ratio trials ($M = 47.34$, $SD = 22.27$) than for high size-ratio trials ($M = 40$, $SD = 19.76$), $F(1, 30) = 13.38$, $p < .01$. However, priming was not different for high size-ratio trials (primed: $M = 45.62$, $SD = 19.66$; non-primed: $M = 34.37$, $SD = 18.48$) than for low size-ratio trials (primed: $M = 54.37$, $SD = 22.13$; non-primed: $M = 40.31$, $SD = 20.39$), $F(1, 30) < 1$.

Although the interaction of priming, condition, and size-ratio factors was not significant, $F(1, 30) < 1$, we depicted it in Table 2 because it was of theoretical interest. We performed t-tests that revealed that in the imagery condition priming was significant both for high size-ratio trials, $t(15) = 3.29$, $p < .01$, and for low size-ratio trials,

$t(15) = 1.81$, $p < .05$, and was not different between both types of trials, $t(15) < 1$. In the same way, in the perception condition, priming was significant both for high size-ratio trials, $t(15) = 3.04$, $p < .01$, and for low size-ratio trials, $t(15) = 3.21$, $p < .01$, and was not different between both types of trials, $t(15) < 1$. The amount of priming was not different between conditions neither for low size-ratio trials, $t(30) < 1$ nor for high size-ratio trials, $t(30) < 1$.

Insert Table 2 about here

We then turned to the analysis on response times for correct identifications. For each subject, response times of less than 150 ms and of more than twice the subject's mean response time were considered as outliers and replaced by the subject's mean response time. We performed an analysis of variance on response times for correct identifications with condition (imagery, perception) as a between-subjects factor, and priming (primed stimulus, non-primed stimulus) and size-ratio (high, low) as within-subjects factors. The analysis showed no overall reliable priming effect, $F(1, 16) = 3.2$. Subjects did not faster identify studied parts ($M = 1204.83$ ms, $SD = 370.39$ ms) than non-studied parts ($M = 1430.93$ ms, $SD = 947.93$ ms). Interaction of priming and condition factors was not significant, $F(1, 16) < 1$. T-tests performed on this interaction showed that

priming was not significant, neither in the imagery condition (primed: $M = 1280.14$ ms, $SD = 453.47$ ms; non-primed: $M = 1464.28$ ms, $SD = 824.37$ ms), $t(14) < 1$, nor in the perception condition (primed: $M = 1110.69$ ms, $SD = 206.47$ ms; non-primed: $M = 1389.25$ ms, $SD = 1110.19$ ms), $t(10) < 1$. Size-ratio did not influence response time, $F(1, 16) = 3.99$ and did not interact with any other factors.

Discussion

As expected, object parts identification was facilitated both when whole objects were perceived (perceptual priming) and imaged (imaginal priming) in the study phase. This result supports the hypothesis that imagery involves the same perceptual representations as those involved in perception. Even though image agreement between photographs we used in the test phase and objects subjects imaged could not be perfectly controlled, results show that it was important enough to elicit priming.

Perceptual and imaginal priming were not different (i.e., perceptual priming was not superior to imaginal priming). Such a result was unexpected and differed from those of McDermott and Roediger (1994). We suggest that the object-part perceptual identification task substantially engages top-down processes. Indeed, in this task the difficulty is twofold. First, only a part of the object is perceived. Second, information provided by that part is degraded by the mask. So, top-down processes are probably

engaged to help identification. As a consequence, there may be a transfer of appropriate processing from the imagery study phase to the perceptual identification task. Such a transfer would have enhanced imaginal priming to the level of perceptual priming.

Large parts were better identified than small ones, but priming was not stronger for low size-ratio trials than for high size-ratio trials, neither when subjects did perceive prime objects in the study phase, nor when they imaged them. The important observation here is that priming did not vary as a function of the object/part size-ratio both in the perception and imagery conditions. This result provides additional evidence that identical representations are activated in imagery and perception.

Experiment 1b

The aim of Experiment 1b was to provide evidence that the representational overlap between imagery and perception depends on the type of images generated. In the study phase of Experiment 1a, subjects had been asked to focus on the detailed parts of objects. Images generated with this type of instructions were detailed images that induced a reliable priming effect in the test phase. In the study phase of Experiment 1b, we used a different type of instructions. To induce the generation of a different type of images, subjects were asked to qualify the object's

contour in terms of “rather angular” or “rather round”. This type of instructions would induce the generation of global images (by contrast to detailed images).

We predicted weaker priming than in Experiment 1a. As subjects imaged the global shape of an object, the representation activated would not overlap with what was then perceived during test (only a part) enough to produce substantial priming. As a consequence, we expected priming by imagery to be less important than priming by perception, contrary to what happened in Experiment 1a.

The size-ratio between studied objects and tested parts was manipulated as in Experiment 1a. Again, we hypothesized the effect of the object/part size-ratio to be identical in the imagery and perception conditions.

Method

Subjects Thirty-two undergraduate and postgraduate students from Lyon 2 University (half female, half male, mean age 20.35 years) participated voluntarily in the experiment.

Materials and apparatus Materials and apparatus were strictly identical to those used in Experiment 1a.

Design and procedure

Design was identical to design used in Experiment 1a: Sixteen subjects participated in the perception condition and sixteen others

in the imagery condition. In each condition, half of the subjects were presented with list A in the study phase, the other half with list B. Finally, four females and four males were assigned to each subgroup of eight subjects.

Procedure was identical to procedure used in Experiment 1a except that in both the imagery and the perception study phases, subjects were asked to judge the object’s contour. In both conditions, subjects responded by pressing either “R” (round) or “A” (angular).

Results

We performed an ANOVA on the percentage of correct identifications in the perceptual identification task. Effects and interactions not reported here were not significant ($p > .05$). However, non significant interactions may be reported when they are of theoretical interest. This was a 2 (condition) x 2 (priming) x 2 (size-ratio) ANOVA, with condition (imagery, perception) as a between-subjects factor and priming (primed stimulus, non-primed stimulus) and size-ratio (high, low) as within-subjects factors.

Results showed an overall reliable priming effect, $F(1, 30) = 24.3$, $p < .01$. Subjects identified more parts extracted from studied objects ($M = 40.78$, $SD = 20.33$) than parts extracted from non studied objects ($M = 30.15$, $SD = 17.86$). The amount of priming was more important in the perception condition (primed: $M = 46.56$, $SD = 19.44$; non-primed: $M = 30$, $SD = 16.65$) than in the imagery condition (primed: $M = 35$,

$SD = 19.84$; non-primed: $M = 30.31$, $SD = 19.25$), $F(1, 30) = 7.5$, $p < .01$. T-tests performed on this interaction showed that priming was significant in the perception condition only, $t(15) = 5.31$, $p < .01$.

Overall the percentage of correct identifications was stronger for low size-ratio trials ($M = 39.22$, $SD = 20.72$) than for high size-ratio trials ($M = 31.72$, $SD = 18.22$), $F(1, 30) = 17.16$, $p < .01$. However, priming was not different for high size-ratio trials (primed: $M = 37.18$, $SD = 17.64$; non-primed: $M = 26.25$, $SD = 18.48$) than for low size-ratio trials (primed: $M = 44.37$, $SD = 22.42$; non-primed: $M = 34.06$, $SD = 17.75$), $F(1, 30) < 1$.

Although the interaction of priming, condition, and size-ratio factors was not significant, $F(1, 30) < 1$, we depicted it in Table 3 because it was of theoretical interest. We performed t-tests that revealed that priming was not significant in the imagery condition neither for high size-ratio trials, $t(15) = 1.16$, nor for low size-ratio trials, $t(15) < 1$. In the perception condition, priming was significant both for high size-ratio trials, $t(15) = 3.07$, $p < .01$, and for low size-ratio trials, $t(15) = 4.87$, $p < .01$, and was not different between both types of trials, $t(15) < 1$.

Insert Table 3 about here

We then turned to the analysis on response times for correct identifications. For

each subject, response times of less than 150 ms and of more than twice the subject's mean response time were considered as outliers and replaced by the subject's mean response time. We performed an analysis of variance on response times for correct identifications with condition (imagery, perception) as a between-subjects factor, and priming (primed stimulus, non-primed stimulus) and size-ratio (high, low) as within-subjects factors. Again no simple effect or interaction was significant. The analysis showed no overall reliable priming effect, $F(1, 15) = 2.5$. Subjects did not faster identify studied parts ($M = 1328.68$ ms, $SD = 501.97$ ms) than non-studied parts ($M = 1218.68$ ms, $SD = 419.24$ ms). The interaction of the factors priming and condition was not significant, $F(1, 15) = 2.97$. T-tests performed on this interaction showed that priming was not significant, neither in the imagery condition (primed: $M = 1376.71$ ms, $SD = 444.28$ ms; non-primed: $M = 1131.19$ ms, $SD = 262.08$ ms), $t(13) = 1.07$, nor in the perception condition (primed: $M = 1285.99$ ms, $SD = 557.54$ ms; non-primed: $M = 1296.45$ ms, $SD = 516.7$ ms), $t(15) = 1.08$. Size-ratio did not influence response time, $F(1, 15) < 1$ and did not interact with any other factors.

Discussion

Results showed that, in contrast to what was observed in Experiment 1a, perceptual priming was stronger than imaginal priming. The comparison of the results of Experiment

1a and 1b, suggest that, as predicted, primes encoding instructions influenced priming in different ways depending on whether primes were perceived or imaged in the study phase. Perceptual priming occurred both when subjects had focussed on the global shape of the perceived objects (Experiment 1b) and when they had counted the parts of the perceived objects (Experiment 1a). In contrast, imaginal priming only occurred when subjects had counted the parts of the imaged objects. When subjects had to judge the contour of the imaged object in the study phase, the global representation activated did not seem to sufficiently overlap with the detailed representation activated while identifying the object part (at test) and no priming was observed. On the contrary, when subjects had counted the parts of the imaged object, detailed representations of the parts of the object were activated. As a consequence, one of the representations activated sufficiently overlapped with the part presented at test to elicit priming. These results support our hypothesis that the representational overlap between imagery and perception varies depending on the types of images generated, given that some images consist in skeletal shapes only whereas others consist in detailed, multi-parts shapes.

As observed in Experiment 1a, large parts were better identified than small ones, but priming did not vary depending on the object / part size-ratio in the perception condition. Priming was not significant in the imagery condition, which did not allow us to

compare perception and imagery conditions regarding the effect of the size-ratio.

Experiment 1c

In both Experiments 1a and 1b subjects in the imagery condition were presented with word-primes in the study phase and had to provide the names of the targets in the test phase. In Experiment 1c, we wanted to ensure that priming by imagery was not caused by a verbal transfer from study to test. This precaution was taken since recent results (Chaffin, Phillips, & Jenei, 1996) suggested that the organization of parts of objects in memory is similar to the organization of categories. Parts would be related to their superordinate wholes by associative links. So, in the imagery study phase, reading the name of the objects may also activate the name of their parts.

Our hypothesis was that priming by imagery is caused by the preactivation of visual representations of objects parts and not by the preactivation of parts names. In Experiment 1c, subjects in the study phase were asked to imagine words, which may increase the putative activation of parts' names. No priming was expected.

Experiment 1c had the same design as Experiments 1a and 1b with two groups of subjects, one presented with words in the study phase and the other one presented with photographs. In Experiment 1c, however, subjects who were presented with a word in

uppercase were asked to imagine the same word in lowercase and to count the number of ascending and descending letters (word-word condition). Subjects who were presented with a photograph of an object were asked to imagine the word corresponding to that object in lowercase and to count the number of ascending and descending letters (image-word condition). We did not expect any priming effect in the word-word condition or in the image-word condition either (even though in this latter condition photographs of objects were presented in the study phase).

Method

Subjects Thirty-two undergraduate and postgraduate students from Lyon 2 University (half female, half male, mean age 21.1 years) participated voluntarily in the experiment.

Materials and apparatus Materials and apparatus were strictly identical to those used in Experiments 1a and 1b.

Design and procedure Design was identical to design used in Experiments 1a and 1b: Sixteen subjects participated in the Word-Word condition and sixteen others in the Image-Word condition. In each condition, half of the subjects were presented with list A in the study phase, the other half with list B. Finally, four females and four males were assigned to each subgroup of eight subjects.

Procedure was identical to procedure used in Experiment 1a except that instructions

in the study phase were different. Subjects in the Word-Word condition were presented with a word in uppercase. Once the word had disappeared, they were asked to imagine this word in lowercase and count the number of ascending and descending letters. Subjects in the Image-Word condition were presented with a photograph of an object. Once the photo had disappeared, they were asked to imagine the word corresponding to this object and count the number of ascending and descending letters. In both conditions, subjects responded by pressing the numerical key corresponding to their count.

Results

We performed an ANOVA on the percentage of correct identifications in the perceptual identification task. Effects and interactions not reported here were not significant ($p > .05$). However, non significant interactions may be reported when they are of theoretical interest. This was a 2 (condition) x 2 (priming) ANOVA, with condition (Word-Word, Image-Word) as a between-subjects factor and priming (primed stimulus, non-primed stimulus) as a within-subjects factor. The factor size-ratio was not included in this analysis as it had no effect in the previous Experiments 1a and 1b. Moreover, this factor was not pertinent for the Word-Word condition since subjects in this condition were not presented with photographs and were not asked to imagine objects.

Results showed no overall priming effect, $F(1, 30) < 1$. Subjects did not identify

more primed parts ($M = 35.47$, $SD = 17.19$) than non-primed parts ($M = 36.09$, $SD = 20.15$). Although the interaction of the factors priming and condition was not significant, $F(1, 30) = 1.8$, we depicted it in Table 4 because it was of theoretical interest. T-tests performed on this interaction showed that priming was not significant neither in the Word-Word condition, $t(15) = 1.2$, nor in the Image-Word condition, $t(15) < 1$.

Insert Table 4 about here

We then turned to the analysis on response times for correct identifications. For each subject, response times of less than 150 ms and of more than twice the subject's mean response time were considered as outliers and replaced by the subject's mean response time. We performed an analysis of variance on response times for correct identifications with condition (Word-Word, Image-Word) as a between-subjects factor, and priming (primed stimulus, non-primed stimulus) as a within-subjects factor. No simple effect or interaction was significant. The analysis showed that subjects did not faster identify studied parts ($M = 1118.86$ ms, $SD = 312.46$ ms) than non-studied parts ($M = 1244.11$ ms, $SD = 454.45$ ms), $F(1, 26) = 2.86$. The interaction of the factors priming and condition was not significant, $F(1, 26) < 1$. T-tests performed on this interaction showed that priming was not

significant, neither in the Word-Word condition (primed: $M = 1105.53$ ms, $SD = 276.84$ ms; non-primed: $M = 1273.79$ ms, $SD = 563.21$ ms), $t(9) = 1.56$, nor in the Image-Word condition (primed: $M = 1130.4$ ms, $SD = 349.64$ ms; non-primed: $M = 1218.39$ ms, $SD = 353.38$ ms), $t(9) < 1$.

Discussion

No priming was observed when subjects imaged words in the study phase, neither when they imaged them from the uppercase versions of the same words (Word-Word condition) nor when they imaged them from the photographs of the corresponding objects (Image-Word condition). Even in the second case, no priming occurred as instructions focussed subjects on the words designating the objects. These results suggest that imaginal priming as observed in Experiment 1a was indeed caused by the preactivation of a visual representation of the part of the object and not by the preactivation of the representation of the word corresponding to this part. Therefore, no verbal transfer seemed to influence the performance in the perceptual identification task.

Experiment 1a revealed that imagery can prime perception via the activation of similar visual representations. As perceptual priming is sensitive to the match in processing flow (top-down versus bottom-up) between study and test phases, we hypothesized that imaginal priming would be

weaker than perceptual priming in a perceptual implicit task. Indeed, in an imagery condition (imaged primes), the match between bottom-up processes engaged in during study and test phases would concern only processes applied to the already generated image. However, imaginal priming we obtained in Experiment 1a was not weaker than perceptual priming. We suggested that this result may stem from the implication of top-down processes in the perceptual test we used. This hypothesis was tested in Experiment 2.

Experiment 2

The aim of Experiment 2 was to examine whether imaginal priming as observed in Experiment 1a was caused by the implication of top-down processes in the object-part perceptual identification task. In other words, is the activation of a similar visual representation in study and test phases sufficient to elicit imaginal priming, or, as suggested by Cabeza et al. (1997), is a match in the *direction* these representations are activated (top-down versus bottom-up) necessary to produce priming?

We hypothesized that the stimuli (masked parts of objects) we employed in the perceptual identification task of Experiment 1a had promoted top-down processes because they were difficult to identify. But the difficulty stemmed from both the limited information contained in a part compared to a

whole object and from degradation induced by the mask. To be able to compare results of Experiment 1a to results of Experiment 2, we decided to use a perceptual identification task in this experiment. So, we used whole masked objects as target stimuli. Using such stimuli may decrease the engagement of top-down processes as more perceptual information is available to identify the stimuli. Our hypothesis was that imaginal priming would be weaker than perceptual priming when the test essentially implied bottom-up processes.

In the study phase, one group of subjects perceived photographs of whole objects and another group imaged the same objects. Both groups had to count the number of parts of the objects. In the test phase, all subjects performed a perceptual identification task in which masked stimuli were the whole studied objects mixed with new ones. A filler task different from the one used in Experiments 1a, 1b, and 1c was proposed between study and test phases. It consisted in counting beeps. Our aim was to use non-verbal stimuli (in contrast to the pseudo-words used in Experiments 1a, 1b, and 1c) to make sure that the filler task materials did not influence the priming effect.

Method

Subjects Thirty-two undergraduate and postgraduate students from Lyon 2 University (half female, half male, mean age 20.12 years) participated voluntarily in the experiment.

Materials and apparatus Materials and apparatus were identical to the ones used in Experiment 1a. The only difference was that test stimuli were the whole objects used in the perception study phase. Eleven new objects were used in training trials at the beginning of the test. We did a pre-test on 30 students to ensure that all the objects had the same level of difficulty when identified in brief and masked presentations without study phase before.

A beep was employed in the filler task in order to create 30 series that differed on the number of beeps they were composed of.

Design and procedure Sixteen subjects participated in the perception condition and sixteen others in the imagery condition. In each condition, half (i.e., eight subjects) were presented with list A in the study phase, the other half with list B. Finally, four females and four males were assigned to each subgroups of eight subjects.

In the perception as in the imagery study phase, the procedure was identical to Experiment 1a. In the perception condition, subjects had to count the number of parts of the objects, and in the imagery condition, subjects had to form the visual mental image of a word's referent inside an empty square and to count the number of parts of the object.

All subjects then performed the filler task. They heard series of two to ten beeps and had to count the number of beeps each

series was composed of. They gave their answer by pressing the numeral key corresponding to their count. All subjects then performed the perceptual identification task. Procedure was identical to Experiment 1a except that stimuli were whole objects. Subjects were asked to identify and name aloud as fast as possible briefly presented objects. The test began with eleven training trials.

Results

We performed an analysis of variance (ANOVA) on the percentage of correct identifications with condition (imagery, perception) as a between-subjects factor and priming (primed stimulus, non-primed stimulus) as a within-subjects factor. Effects and interactions not reported here were not significant ($p > .05$). However, non significant interactions may be reported when they are of theoretical interest.

A reliable priming effect was revealed, $F(1, 30) = 19.82, p < .01$. Subjects identified more studied objects ($M = 49.68$) than non-studied objects ($M = 37.65$).

As expected, priming varied depending on the condition $F(1, 30) = 6.77, p < .02$. This interaction is illustrated in Table 5. T-tests performed on this interaction showed a reliable priming in the perception condition, $t(15) = 4.98, p < .01$, but not in the imagery condition, $t(15) = 1.31$. Additional t-tests showed that although subjects in the perception condition seemed to identify more primed objects than subjects in the imagery

condition, this effect was not significant, $t(15) = 1.25$.

Insert Table 5 about here

We then turned to the analysis on response times for correct identifications with condition (imagery, perception) and priming (primed stimulus, non-primed stimulus) as factors. For each subject, response times of less than 150 ms and of more than twice the subject's mean response time were considered as outliers and replaced by the subject's mean response time. The analysis revealed that primed stimuli ($M = 841.78$ ms) were not identified faster than non-primed stimuli ($M = 916.994$ ms), $F(1, 28) = 3.22$, $p < .09$. Moreover, priming did not vary depending on the condition, $F(1, 28) = 2.60$. However, as this interaction was of theoretical interest, we performed t-tests that revealed a significant priming in the perception condition (primed: $M = 758.34$ ms, non-primed: $M = 901.22$ ms), $t(14) = 2.19$, $p < .05$, but not in the imagery condition (primed: $M = 925.22$ ms; non-primed: $M = 932.77$ ms), $t(14) < 1$.

Discussion

As expected, priming observed in the whole objects perceptual identification task varied depending on whether subjects had perceived or imaged prime objects in the study phase. Indeed, priming reached significance in the

perception condition only. These results were confirmed by those obtained in the complementary analyses on response time. They suggested that imaginal priming falls under significance when there is less of a match between the top-down processes involved in image generation and the top-down processes involved in the perceptual test. These results are in accordance with those of Cabeza et al. (1997).

Note that performance in Experiment 2 was higher than in every previous experiment. This result suggested that identifying whole objects was easier than identifying parts of objects (Experiments 1a, 1b, 1c). This result supports our hypothesis that using whole objects decreases the engagement of top-down processes as more information is available to identify the stimuli.

In general, our results suggest that visual priming effects are very sensitive to the fact that cognitive processes engaged in during study and test phases go in the same direction. A perceptual overlap between representations activated in the two phases may be necessary, but sometimes not sufficient to produce priming.

General Discussion

The goal of the present experiments was to examine the representational and functional overlap between imagery and perception using a priming paradigm. Overall, data revealed that imaginal priming can be observed. As priming on perceptual implicit

tests has been shown to be sensitive to the physical overlap between prime and target stimuli, we can assume that imaged objects sufficiently shared perceptual features with the corresponding percepts to produce reliable priming. This result suggests that the perceptual representations involved in visual imagery are identical to those involved in visual perception. These representations may correspond to those of the Perceptual Representation System (Schacter, 1992), or to those of the Pattern Activation Subsystem (Kosslyn & Koenig, 1992), that is to representations of whole object shapes and object parts stored in a “form system”. Data converge to locate such a “form system” in the inferior temporal part of the brain (i.e., the visual ventral stream) (for a review, see Ungerleider, 1995).

We assumed that imagery and perception activate the same perceptual representations but through two different neural pathways, top-down and bottom-up respectively. The Transfer Appropriate Processing (TAP) theory (Morris, Bransford, & Franks, 1977) posits that memory performance depends on the match between study and test phases cognitive operations. Recent results demonstrated that priming is indeed sensitive to the fact that processes involved in study and test phases go in the same direction (Cabeza et al., 1997). As a consequence, we expected imaginal priming to be inferior to perceptual priming in a perceptual implicit test. This difference did

not appear in Experiment 1a. This result is not consistent with the one of McDermott and Roediger (1994) that revealed that imaginal priming was half as much as perceptual priming in a picture fragment identification task. We suggest that the object-part perceptual identification task we used substantially engages top-down processes. As a consequence, a transfer of appropriate processing would have raised imaginal priming to the level of perceptual priming. We assume that using masked parts of objects as stimuli may trigger top-down processes, given that such stimuli are difficult to identify both because a part provides less information than the whole object and because even that is degraded by the mask. According to Kosslyn (1994), difficult identification triggers additional processing. This may consist in generating an image from memory that corresponds most to the input, in order to operate a top-down matching. So, the identification of masked parts of objects, being difficult, may have induced top-down processes. An important transfer of top-down processing from imagery activity to degraded stimuli identification would have occurred. As processing transfer has been shown to improve memory performance (Blaxton, 1989; Roediger & Blaxton, 1987b; Roediger, Weldon, & Challis, 1989), imaginal priming would have been enhanced so as to reach the level of perceptual priming. As a consequence the expected difference between both types of priming disappeared.

To explore the overlap (in terms of the proportion of perceptual features activated) between representations activated by imagery and representations activated by perception, we used large and small parts of objects as target stimuli (Experiments 1a, 1b). We expected large parts to overlap with the original object more than small ones and therefore, to elicit more priming. Results revealed that priming was not stronger for large parts than for small ones. However, the independence of priming regarding the variation of the object/part size-ratio was similar in the imagery and perception conditions. We propose that priming size invariance might explain these results. Priming size invariance has been observed in a series of priming experiments by Biederman and Cooper (1992), Cooper, Biederman, and Hummel (1992) and Cooper, Schacter, Ballesteros, and Moore (1992). These authors demonstrated that priming was not reduced by object size variation between study and test phases. These results make sense when considering the distinction between representations underlying objects shape recognition, that may correspond to the perceptual representations of the ventral visual system, and representations underlying metric or coordinate relations between objects or parts of objects, that may correspond to the perceptual representations of the dorsal visual system (see Ungerleider & Mishkin, 1982). Representations for recognition do not seem to be metrically specified, given that human shape recognition appears to be invariant with

changes of size, orientation or position in the visual field. Such representations are named structural representations as they represent objects as sums of parts and spatial relations between parts. Perceptual priming is assumed to be mediated by the activation of such structural representations, which would explain our results. Concerning imagery, results were similar to those observed in perception: The object/part size ratio did not influence priming. As perceptual and imaginal priming were both size invariant, we can conclude that both activities rely on the activation of the same representations. These representations are not sensitive to the size, just as representations stored in the Pattern Activation Subsystem that is part of the ventral system.

The results of Experiment 1a and 1b suggest that the representational overlap between imagery and perception depends on the type of images generated. As perception corresponds to a detailed analysis of the stimulus, we hypothesized that representations activated by imagery and by perception would be more similar when detailed multi-parts images are generated than when skeletal images are generated. Indeed, imaginal priming only occurred when, in the study phase, subjects had to count the object's parts (Experiment 1a) but not when they had to judge the object's contour (round versus angular) (Experiment 1b). The first type of instructions was supposed to induce activation of detailed parts of the object,

whereas the second type would induce activation of its global shape only. Of course, to image the global shape of an object implies that parts of this object are activated as these parts form the contour of the object. What we assume is that when a global image is generated, parts of the imaged object are not as detailed as when a detailed image is generated. Indeed, priming data suggest that when subjects imaged a global object, the activated representation did not perfectly overlap with the representation activated while perceiving the same object. No priming occurred when these subjects then had to identify a part of the object. In contrast, when subjects imaged a detailed object (detailed parts), the activated representations seemed to be very similar to the representation activated while perceiving the same object. Indeed, priming occurred when these subjects then had to identify a part of this object.

Priming from imagery was not due to a verbal transfer from study to test. Our results revealed that reading and imaging the names of later presented objects did not elicit priming on a perceptual identification task, though the task involved naming (Experiment 1c). This result demonstrates that imaginal priming was not caused by a verbal transfer from the names of the primes encountered in the study phase to the name of the parts of objects presented in the perceptual identification task. Imaginal priming is mediated by the perceptual overlap

between the visual representations activated by imagery and the visual representations activated by performing the perceptual identification task. This result does not support the hypothesis that priming elicited by image generation from a name depends on the fact that the implicit perceptual test employed requires naming (Cabeza et al., 1997).

Results from Experiment 1a suggested that top-down processes were involved in the object-part perceptual identification task. The question then was whether imaginal priming was caused by the implication of such processes in the task. To answer this question we employed a perceptual identification task made of whole objects as stimuli (Experiment 2), which was supposed to reduce top-down processing. Results revealed a difference between perceptual priming and imaginal priming. In fact, imaginal priming fell under significance. These results are in accordance with those of Cabeza et al. (1997). They suggested that imagery may not prime perception when the implicit perceptual test employed does not require top-down processing. So, it seems that differences in priming from imagery and perception can be explained by the degree to which cognitive processes involved in the study phase match those involved in the test phase, given that imagery engages essentially top-down processes and perception, bottom-up processes. These results also suggest that the match in the direction of processing involved

in study and test phases critically influences priming, as does the physical overlap between the activated representations themselves. In addition, these results provide confirmation that the object-part perceptual identification task substantially engaged top-down processes, which raised imaginal priming to the level of perceptual priming (Experiment 1a).

In conclusion, the examination of imaginal priming in a perceptual implicit task provided evidence (a) that the representations activated to image an object are identical to those activated to identify the same object. We propose that these representations are located in a “visual form” system that stores representations of shape of objects that are independent of metric properties; (b) that, however, the representational overlap between imagery and perception depends on the type of mental images generated (skeletal versus detailed images); and (c) that imaginal priming depends on the degree of implication of top-down processes in the perceptual task employed. This suggests that what matters for visual priming in general is not just the physical overlap between study and test stimuli but also the match in the direction (top-down versus bottom-up) of processing engaged in during study and test phases.

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Table 1

Examples of stimuli used in Experiments 1a, 1b, and 1c. Whole objects names or photographs were presented in the study phase and photographs of parts of objects were presented in the test phase. The size-ratio describes the size of the part compared to the size of the whole object.

STIMULUS	PART	SIZE-RATIO
Vélo / bike	Guidon / handlebars	High
Canard / duck	Patte / foot	High
Pistolet / gun	Gâchette / trigger	High
Aigle / eagle	Bec / beak	High
Avion / plane	Aile / wing	High
Lampe / lamp	Abat-jour / lampshade	Low
Biberon / baby bottle	Tétine / teat	Low
Cerf / elk	Bois / antler	Low
Moulin / windmill	Pales / blades	Low
Montre / wristwatch	Bracelet / wristband	Low

Table 2

Mean percentage of correct identifications in the test phase of Experiment 1a as a function of the factors study condition (imagery, perception), priming (primed stimulus, non-primed stimulus) and size-ratio between prime object and target part (low, high). Standard deviations between parentheses.

	IMAGERY CONDITION		PERCEPTION CONDITION	
	Primed stimuli	Non-Primed stimuli	Primed stimuli	Non-Primed stimuli
High Size-Ratio	51.87 (19.39)	41.25 (16.28)	39.37 (18.43)	27.5 (18.44)
Low Size-ratio	56.25 (23.06)	45.62 (15.04)	52.5 (21.75)	35 (23.94)

Table 3

Mean percentage of correct identifications in the test phase of Experiment 1b as a function of the factors study condition (imagery, perception), priming (primed, non-primed stimulus), and size-ratio (low, high). Standard deviations between parentheses.

	IMAGERY CONDITION		PERCEPTION CONDITION	
	Primed stimuli	Non-Primed stimuli	Primed stimuli	Non-Primed stimuli
High Size-Ratio	33.12 (15.37)	26.87 (19.57)	41.25 (19.28)	25.62 (15.47)
Low Size-ratio	36.87 (23.86)	33.75 (18.93)	51.87 (18.69)	34.37 (17.11)

Table 4

Mean percentage of correct identifications in the test phase of Experiment 1c as a function of study condition (Word-Word, Image-Word) and priming (primed stimulus, non-primed stimulus) factors. Standard deviations between parentheses.

	WORD-WORD CONDITION	IMAGE-WORD CONDITION
Primed stimuli	34.06 (18.55)	36.87 (16.21)
Non-Primed stimuli	37.81 (22.21)	34.37 (18.43)

Table 5

Mean percentage of correct identifications in the test phase of Experiment 2 as a function of study condition (imagery, perception) and priming (primed stimulus, non-primed stimulus) factors. Standard deviations between parentheses.

	IMAGERY CONDITION	PERCEPTION CONDITION
Primed Stimuli	44.37 (21.12)	55 (26.64)
Non-Primed Stimuli	39.37 (19.22)	35.94 (22.07)