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What is primed in priming from imagery?

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Abstract Priming from imagery is typically weaker than that from perception. This has been interpreted as resulting from weaker activation of perceptual processes. However, for imagery and perception, commonality is only half the story: Each is also characterized by specific processes. If priming can be due to both unshared and shared components of imagery and perception, then it should be possible to observe greater priming from imagery than from perception. Two new priming experiments were designed to test this hypothesis, while controlling incidental task differences. In both experiments, participants studied objects by counting their parts (from a mental image or a picture). Experiment 1 used a word-picture matching test task, which was hypothesized to depend on stimulus processing specific to perception, and Experiment 2 a size judgment test task, which was hypothesized to depend on retrieval and generation processes specific to imagery. As predicted, priming for perceived objects was greater than priming for imagined objects in the word-picture matching task. Conversely, in the size judgment task, more priming from imagery than from perception was observed. These results support the conclusions that (a) imagery and perception have substantial unshared processes, and (b) these processes contribute to priming.

Introduction

Visual mental imagery refers to the human ability to visualize objects that are not present in the environment. Mental imagery is striking in its phenomenology – a vivid mental image provokes the sense of examining a "mental picture" as if it were a physical object. This has motivated many to wonder to what extent do the brain and mind respect these vivid intuitions, that is to what extent mental images are similar to perceptions? However, there is another side to the coin: In what ways do the processes by which mental images and perceptual representations are generated differ? In this study, we address this question using the technique of repetition priming.

Over the past 30 years, many studies have been conducted that aimed at showing the similarity between visual mental imagery and visual perception. Behavioral (Farah, 1988; Ishai & Sagi, 1997; Kosslyn, 1975; Shepard & Cooper, 1982), neuropsychological (Bisiach & Luzzatti, 1978; Levine, Warach, & Farah, 1985) and neuroimaging results (D'Esposito, Detre, Aguirre, Stallcup, Alsop, Tippet, & Farah, 1997; Klein, Paradis, Poline, Kosslyn, & Le Bihan, 2000; Mellet, Tzourio, Denis, & Mazoyer, 1998) suggest that imagery and perception indeed have common properties and share neural substrates. Motivated by the hypothesized similarity between the two, researchers have shown that imagery can produce priming in situations in which perceiving words (Pilotti, Gallo, & Roediger, 2000; Roediger & Blaxton, 1987a; Roediger, Weldon, Stadler, & Riegler, 1992; Schacter & Graf, 1989; Stuart & Jones, 1996) or pictures (Cabeza, Burton, Kelly, & Akamatsu, 1997; McDermott & Roediger, 1994; Michelon & Koenig, 2002) produce priming. However, the priming observed is typically weaker than that observed for perceptual study conditions. In other words, the facilitation induced by imagining objects prior to perceiving pictures representing those objects (priming from imagery) is typically weaker than that produced by repeating the same pictures (priming from perception).

Priming effects have been extensively studied in the implicit memory domain. The transfer-appropriate processing account of memory (TAP) has stressed the importance of the overlap between the cognitive processes engaged during the first (study) and second (test)

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presentations (Blaxton, 1989; Roediger & Blaxton, 1987b; Roediger, Weldon, & Challis, 1989). The amount of priming is predicted to depend on the extent to which these processes are similar. One possibility is that imagery leads to priming on perceptual tests because it engages visual processes, but leads to less priming than perceptual study conditions because imagery activates these processes to a lesser extent than does perception (McDermott & Roediger, 1994). Such a proposition seems attractive since it accounts for the subjective feeling that visual images are less vivid than percepts.

However, when it comes to priming there may be more to imagery and perception than their similarities. Despite the considerable overlap between imagery and perception, each of the two likely involve specific neural systems. Support for such a proposition can be found in different models of imagery and perception (see Kosslyn, 1994; or Behrman, Moscovitch, & Winocur, 1994). For instance, in Kosslyn's (1994) model, on one hand, 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 perceptual, visual representations in a 'pattern activation subsystem' (PAS). As a consequence, a spatial pattern of activation is projected onto a 'visual buffer'. This pattern is 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. On the other hand, perception starts with a pattern of activation in the visual buffer. This pattern is pre-processed in a 'pre-processing subsystem' and then activates a matching stored representation in the PAS. Finally, the name of the perceived object and information associated with this object is found in associative memory. Using this model, one can easily show that, although some systems such as associative memory, the PAS or the visual buffer are shared by imagery and perception, others are specific to each activity. For instance, the lookup subsystems are specific to imagery, whereas the pre-processing system is specific to perception.

The neuropsychological literature supports the idea that imagery and perception involve specific processes. The two activities have been doubly dissociated, with some patients showing impaired perception and preserved imagery (Bartolomeo, Bachoud-Levi, & Denes, 1997; Behrman et al., 1994; Michelon & Biederman, *in press*) and others the opposite (Luzzatti & Davidoff, 1994; Riddoch, 1990). Similar results have been obtained with functional neuroimaging. In a PET study comparing imagery and perceptual tasks, Kosslyn, Thompson and Alpert (1997) reported that out of a total 21 areas involved in visual processes, 66% were activated during both imagery and perception, 10% during perception only, and 24% during imagery only.

It follows from the TAP analysis of priming that the magnitude of priming from imagery, as well as the magnitude of priming from perception, should depend on the type of processes involved in the test task (Cabeza et al., 1997; Michelon & Koenig, 2002; Stadler & McDaniel, 1990; Stuart & Jones, 1996; Wippich, Mecklenbrauker, & Halfter, 1989). If the components of imagery that lead to priming are solely those that are shared with perception, priming from perception should always be greater. However, if priming from imagery can arise from the processing components that aren't shared, then it should be possible to construct situations in which imagery leads to greater priming than perception. This would be the case when the performance in the test task relies mainly on imagery processes.

There is a limited body of data that bears on this question. Wippich et al. (1989, Experiment 2) used an imagery test in which participants spelled words from mental images of the words. Two study tasks were used: a perceptual task in which participants spelled each word while looking at it printed on a card, and an imagery task in which the card was taken away before the spelling began. They observed robust priming from the imagery study task to the test task, and no priming from the perceptual study task.

The results of Wippich et al. (1989) provide an example of greater priming from imagery but, as their theoretical interest was focused elsewhere, no perceptual test condition was included. An experiment reported by Stadler and McDaniel (1990) included imagery and perception conditions at both study and test. They asked participants to count ascending (e.g., d, l, k) and descending letters (e.g., q, p, j) in words presented in upper or lower case. They reasoned that when the words were presented in upper case participants would form a mental image of the lower case version to answer the question. Thus, lower case presentation constituted a perceptual condition, and upper case presentation an imagery condition. A continuous performance paradigm was used, in which words were repeated during performance of the task, either in the matching (e.g., lower case – lower case) or mismatching case (e.g., lower case – upper case). When participants were instructed to use imagery to solve the task, a crossover pattern was observed, indicating priming of imagery from imagery and from perception, and priming of perception from perception but not from imagery. The pattern of priming of imagery is consistent with the TAP account. However, this interpretation must be qualified by the fact that the difference in priming from imagery and from perception was not statistically reliable. Based on this, the authors argued that the data indicate that priming from perception to imagery reflected shared processes operating on equivalent representations.

Finally, Cabeza et al. (1997, Experiments 1a and 1b) combined perceptual and imagery study tasks with perceptual and imagery test tasks in a study of face perception. At study, participants either imagined a celebrity's face for 8 s and rated the quality of their image, or examined a picture of a celebrity for the same length of time and then indicated the person's profession. At test, in the perception task participants were asked to decide whether pictures of people depicted known people, and in the imagery task participants were presented with a name and asked to imagine whether the person named had a mole (Experiment 1a) or had light or dark hair (Experiment 1b). In both experiments priming on the perception test task was greater when the item had been seen at study, and the converse was true for the imagery test task. However, some methodological questions cloud interpretation of these data. In particular, the perception and imagery study tasks differed in incidental features such as the goal of the response required (image quality vs person's profession).

In sum, there is ample evidence that for test tasks where priming depends on processing a visual stimulus, priming from perception is stronger than priming from imagery. For test tasks depending on memory retrieval and image generation, imagery study tasks appear to lead to greater priming. However, a direct test that image generation processing can independently lead to priming requires two conditions be met, which are satisfied by no previous studies. First, the same imagery and perceptual tasks should be used at study and only the test task should vary to produce both greater priming from imagery and greater priming from perception. Otherwise differences in the overall amount or quality of processing in each study condition could lead to spurious differences in priming. Second, task demands need to be identical in the imagery and perceptual study tasks. Otherwise, differences in priming could be due to overlap between task demands at study and test rather than visual processing at study and test.

Most of the relevant previous research, having been aimed at other theoretical issues, fails to meet the first condition. As noted, most previous priming studies including imagery study conditions used only perceptual test conditions. The experiment of Wippich et al. (1989) included only an imagery test condition. Cabeza et al.'s (1997) study does not meet the second condition, leaving open the possibility that the difference between the task demands of the two encoding tasks they used (rating the quality of visual images and making decision about celebrities' occupation) may have been responsible for priming differences between imagery and perception. The experiment of Stadler and McDaniel (1990) meets both conditions but, as noted, did not produce clear evidence of priming from unshared processing.

The two experiments reported here were designed to provide a strong test of the hypothesis that processes not shared between imagery and perception could produce differential priming under appropriately controlled conditions. To satisfy the first condition we designed two experiments in which the same pair of imagery and perception study tasks were used. Only the criterion test varied. To satisfy the second condition, in the two experiments reported here, the imagery and perception study tasks had identical demands: counting of objects' parts.

Experiment 1 was designed to test the hypothesis that when the test task involves processes specific to perception, priming is greater from a perceptual study task than from an imagery study task. In the study phase, one group of participants counted objects' parts from pictures and another group from mental images. The first of these tasks requires bottom-up processing of the visual stimulus leading to enumeration of the object's parts. The second requires top-down activation of object parts based on an abstract representation in associative memory. In the test phase, participants read a word and then decided whether a picture depicted the word's referent. The delay between presentation of the word and the picture was long (2,000 ms) to allow adequate time for reading the word, so that response time would depend on the speed with which the participant could visually process the picture. Identifying an object from a picture relies on bottom-up processing of the visual stimulus leading to identification of the depicted object. In terms of Kosslyn's (1994) model, this processing cascade overlaps greatly with that described for counting parts from pictures, but not with that for counting parts from mental images. We therefore hypothesized that for this test task perception would lead to greater priming than imagery.

Experiment 2 was designed to test the hypothesis that when the test task involves processes specific to imagery, priming is greater from an imagery study task than from a perceptual study task. The two study tasks were identical to the ones of Experiment 1. Only the test task was varied between the two experiments: In Experiment 2, participants performed a size judgment task in which they decided whether a named object was smaller or larger than a proposed size. The size was presented first, followed by a delay (2,000 ms), so that response time would depend on the speed with which participants could access the object's size based on the object's name. This requires top-down activation of object properties. This processing cascade overlaps significantly with that described for counting object parts from imagery, but not with that for counting parts from perception. Therefore, we hypothesized that for the size judgment task imagery would lead to greater priming than perception – unlike that proposed for Experiment 1.

In short, we predicted that a task in which response time depends primarily on the identification of an object by feed-forward processing of a visual stimulus would be primed best by a perceptual study condition. Conversely, we predicted that a task in which response time depends primarily on the lookup of object properties from a long-term memory representation would be primed best by an imagery study condition. In both cases these predictions derive from an analysis of the overlap between processing components practiced by the study tasks and those determining response latency in the test task.

Experiment 1

Experiment 1 was a two-phase priming experiment. In the study phase, one group of participants imagined objects and another group perceived objects. All participants were instructed to count the objects' parts. These instructions aimed at focusing participants' attention on the perceptual features of the stimuli. In the test phase, we used a word-picture matching task in which each picture was preceded by a word that either matched the picture or not. The participants' task was to decide whether or not the picture represented the word's referent (word-picture matching). A filler task (counting beeps) was performed between study and test in an attempt to prevent participants from using an explicit strategy of recuperation of studied objects in the test phase.

Performance in the word-picture matching task depends on the speed at which the picture is identified before it can be matched to the word previously presented. We chose an inter-stimulus interval (ISI) of 2,000 ms between the onset of the word and the onset of the picture to ensure that the word was fully and deeply processed. Scheerer-Neumann (1974) showed that using an ISI of 2,000 ms, reaction times to word-picture pairs were as fast as those to picture-picture pairs, suggesting that both visual and verbal information was extracted from the word cue.

Given the processes involved at study and test (detailed in the Introduction), its was expected that priming in the perception group would be greater than priming in the imagery group. This is a pattern that has been typically reported in the past (McDermott & Roediger, 1994; Pilotti et al., 2000).

Method

Participants

Forty-eight students from Washington University (30 female, mean age 19.31 years) participated in the experiment for psychology-course credit requirement. All had normal or corrected-to-normal vision and were native English speakers.

Materials

One hundred and thirty-six black and white photographs of objects and animals were used. Photographs were scanned from commercially available books and magazines. Each photograph subtended a visual angle of approximately 9 degrees horizontally and vertically (see examples in Fig. 1). Three lists (A, B, C) of 40 items each were designed. For each participant, one list was studied (e.g., list A), another was used as nonstudied items in the test (e.g., list B), and the last one was used as filler pictures in the mismatching pairs in the test (e.g., list C). Across participants each list was used an equal number of times as studied, nonstudied and filler list. The order of the stimuli (forward versus reversed) in each list was counterbalanced between participants. Test stimuli were pairs of words and pictures, half matching and half mismatching. Sixteen additional pairs were always used at the beginning of the test as practice trials.

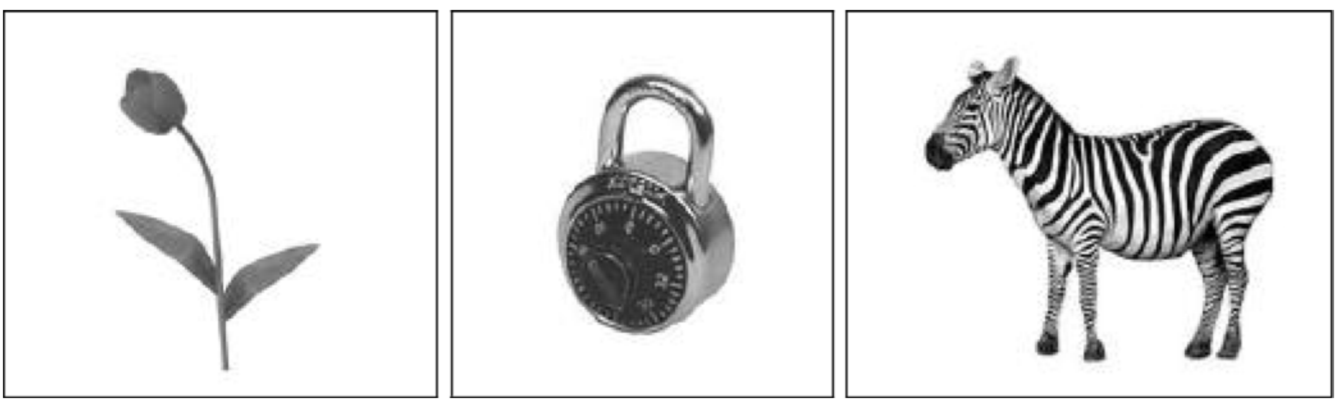

Fig. 1 Examples of stimuli used in the perception study conditions of Experiments 1 and 2 and in the word-picture matching task of Experiment 1

Design and procedure

This was a mixed design with Condition (imagery, perception) as a between-participants factor, and Priming (studied stimulus, nonstudied stimulus) and Match (match, mismatch) in the word-picture matching task as within-participants factors. During the study phase, participants ($n = 24$) in the perception study group were presented with photographs of objects and asked to count the number of parts of each object. They were told that the level of detail at which to divide the object was up to them but that they should use the same criteria throughout the task. Each trial began with a fixation point presented for 1,000 ms. After 100 ms, a photograph appeared and remained on the screen for 8 s. A beep rang 7 s after the presentation of the photograph to cue participants to respond. Responses were given orally and registered by the experimenter. The inter-trial interval was of 1,500 ms.

During the study phase, participants ($n = 24$) in the imagery study group were presented with words in uppercase. For each word, they were asked to form the visual mental image of the word's referent and count the number of parts of the imaged object. The fact that the definition of a part was subjective was emphasized as in the perception condition. Each trial was identical to trials in the perception condition except that a word (instead of a photograph) appeared for 1,000 ms. An empty square in which participants had to form the mental image followed the presentation of the word. It was presented for 8 s. A beep rang 7 s after the presentation of the square to invite participants to respond. Responses were given orally and registered by the experimenter.

All participants performed the filler task after the study task. It lasted approximately 5 min. They heard 20 series of two to ten beeps and counted the number of beeps for each series. Responses were given orally and registered by the experimenter. Response time was limited as the computer started each new series automatically 1,000 ms after the end of each series.

After the filler task, each participant performed the word-picture matching task. Each trial began with a blank screen for 2,000 ms, followed by a fixation point for 500 ms to alert the participant to the impending stimulus. After a blank screen for 500 ms, a word was presented for 100 ms. The word was followed by a cross that remained on screen for 2,000 ms, followed by a target picture that was presented for 100 ms. The screen then remained blank until the participant indicated whether the word and picture matched, by pressing a button box key for "yes" or "no" (assignment of the left and right button box keys to "yes" and "no" was counterbalanced across participants). Reaction times were measured from the disappearance of the picture. The test began with 16 training trials. Then, all participants were presented with 80 items. For each participant, half of the items were studied and the other half were not. For both studied and nonstudied items, half required a yes answer (match pairs) and the other half a no answer (mismatch pairs). Across participants, each item appeared both in match and mismatch trials. Participants were not told that some items were repeated from study to test.

Results

Accuracy in the word-picture matching task was high. Participants in the imagery group, answered a mean of 96.67% of studied items correctly (SD = 5.29), and 95.73% of nonstudied items (SD = 4.12). Participants in the perception group answered a mean of 96.98% of studied items correctly (SD = 4.34), and 96.25% of nonstudied items (SD = 4.32). As a consequence we did not perform an analysis on error rates but only on response times for correct responses. We carried out a 2 × 2 × 2 ANOVA, with Condition (imagery, perception), Priming (studied stimulus, nonstudied) and Match (match, mismatch) as factors. Outliers, defined as response times greater than two SDs from the participant's mean for that condition were discarded. On average, 3.98% of latencies for correct responses were excluded.

There was a reliable overall priming effect: Participants responded faster to studied ($M = 543$ ms, SD = 138 ms) than to nonstudied stimuli ($M = 562$ ms, SD = 133 ms), $F(1, 46) = 33.88$, $P < 0.01$. As predicted, the interaction between the Priming and Condition factors showed that priming was greater in the perception condition than in the imagery condition, $F(1, 46) = 15.44$, $P < 0.01$. This result is illustrated in Table 1. t-tests showed that priming was statistically reliable in the perception condition, $t(23) = 7.08$, $P < 0.01$, but not in the imagery condition, $t(23) = 1.37$, $P = 0.18$.

Overall, participants responded faster to match trials ($M = 536$ ms, SD = 136 ms) than to mismatch trials ($M = 569$ ms, SD = 134 ms), $F(1, 46) = 41.97$, $P < 0.01$. Priming was greater for match than for mismatch trials, $F(1, 46) = 5.9$, $P < 0.02$, as shown by the interaction of Priming and Match factors. Mean response times for studied and nonstudied items were 521 ms and 550 ms, respectively (SDs = 141 and 131) for match trials, and 564 ms and 574 ms, respectively (SDs = 133 and 136) for mismatch trials. t-tests showed that priming was reliable for both match and mismatch trials, $t(47) = 4.75$, $P < 0.01$, and $t(47) = 2.14$, $P < 0.04$, respectively. The interaction of the Match and Condition factors was not statistically reliable, $F(1, 46) < 1$.

Table 1 Response time (in ms) for correct responses in the imagery and perception conditions of the word-picture matching task (Experiment 1) as a function of the priming factor (studied, nonstudied). SDs in parentheses

	Studied	Nonstudied
Imagery	558 (140)	564 (141)
Perception	528 (135)	560 (127)

Participants in the two conditions did not differ reliably in their overall speed of responding, $F(1, 46) = .21$, $P = 0.65$. The three way interaction between Priming, Match and Condition was also not reliable, $F(1, 46) = 0.11$, $P = 0.74$.

Discussion

As predicted, the significant interaction of the priming and condition factors showed that priming from perception was much stronger than priming from imagery (which did not reach significance) in a word-picture matching task. This result replicates previous results from studies using pictures in a perceptual criterion task (McDermott & Roediger, 1994).

The results of this experiment are consistent with the view that priming from imagery results from weaker activation of the same visual processes that are activated by perception (McDermott & Roediger, 1994). These results are also consistent with the alternative presented in the Introduction, namely that imagery and perception can both lead to priming through overlap between specific processing at study and test. That account predicts relatively greater priming from perception in this experiment because of the test task's dependence on bottom-up activation of visual representations, which should overlap most with a perceptual study task involving the same stream of bottom-up processes. The fact that priming from imagery did not reach significance supports this analysis. The conceptually driven stream of processing involved in the imagery study task did not provide a basis for priming in the word-picture matching task.

There are two potential concerns regarding the finding that perception produced greater priming than imagery in this experiment. The first applies to any use of an imagery study phase with a perceptual test phase. If participants in the imagery study condition generated mental images that were quite different from the pictures studied by the perception group, then, when those pictures were shown in the test phase, the imagery group could have suffered from interference between their images from the study phase and the presented pictures. However, aspects of the data militate against this explanation. Results from the part counting task indicate that the number of parts counted for each object was highly correlated between the imagery and perception groups, $r = 0.71$, $t(118) = 10.26$, $P < 0.001$. To test whether the two groups differed in how they performed the part counting task, we conducted a 2 (group) × 120 (object) mixed ANOVA. The perception ($M = 5.20$, SD = 2.43) and imagery ($M = 4.40$, SD = 2.50) groups did not statistically differ in the number of parts they described, $F(1, 1{,}559) = 1.09$, $P = 0.30$. More importantly, there was no evidence of a group by object interaction, $F(1, 1{,}559) = 0.45$, $P = 1.00$. This result is consistent with the idea that mental images generated in the imagery condition were close to pictures presented in the perceptual condition.

Second, one could argue that participants used a name-matching strategy (by naming the pictures) rather than a picture matching strategy in the test, which could have benefited the perception condition if participants had already automatically named pictures at study. However, data reported by Scheerer-Neumann (1974) provide evidence against such a proposition. Scheerer-Neumann showed that with a long interval between words and pictures, as used in the present study, participants' strategy is to re-code words into a pictorial code rather than re-coding pictures into a verbal code. This implies that speed of responding in the task depends primarily on the time required to perceptually process the target picture.

Note that priming was greater for match than for mismatch trials, which could be explained by the fact that in match trials pictures were primed twice: once at study and a second time at test via the matching words preceding the pictures.

Having replicated the typical finding of greater priming from perception than from imagery in Experiment 1, our aim in Experiment 2 was to test whether the opposite pattern could be generated by selecting a test task whose processes would overlap with those involved selectively in imagery, but not perception.

Experiment 2

In Experiment 2 the two study conditions of Experiment 1 were tested with a different test task designed to depend heavily on top-down processes hypothesized to be required by the imagery study condition. The only substantive difference between Experiments 1 and 2 was the criterion test. Whereas in Experiment 1 participants read an object name and then verified that a picture matched the name, in Experiment 2 participants read an object name and judged whether the object named was larger or smaller than a previously-presented size.

On each trial of the size judgment task, participants were visually presented with an object name in uppercase letters and a size in feet and inches. For each name, they were asked whether the referent of the word was smaller or larger than the size shown. Previous results have shown that in such tasks, the closer the objects' size, the longer it takes to compare them (Kosslyn, Murphy, Bemesderfer, & Feinstein, 1977; Paivio, 1975). Because this function is similar to the one obtained when subjects make direct perceptual comparisons, the task is thought to be mediated by the use of internal analog representations that contain relative size information, that is visual mental images (Paivio, 1975). To encourage participants to imagine an object to decide whether it was larger or smaller than the presented size, we used only sizes that were close to the objects' actual sizes.

Given the processes involved in the study and test tasks (detailed in the Introduction), we predicted that in the size judgment task priming from imagery would be greater than priming from perception.

Method

Participants

Sixty-four students from Washington University (46 female, mean age 19.5 years) participated in partial fulfillment of a course requirement. All had normal or corrected-to-normal vision and were native English speakers.

Materials

Ninety-six black and white photographs of objects and animals were used. These were selected at random from the pictures used in Experiment 1. Two lists A and B of 40 items each were formed. Across participants each list was used an equal number of times as a studied and a nonstudied list. The order of presentation was counterbalanced across participants. In the test, each word was presented with a size in feet and inches. Sixteen additional items were presented at the beginning of the test as practice trials.

We performed a pretest with 22 participants to collect normative sizes. In this pretest, participants were presented with the name of the 96 items and were asked to estimate the size of each object along its longest axis. Estimates were then averaged for each item (e.g., poodle: $M = 23$ inches, $SD = 9$ inches; pliers: $M = 6.5$ inches, $SD = 1.5$ inches; ladle: $M = 12$ inches, $SD = 5$ inches). Our aim was to have two size estimates for each item: one larger than its actual size and one smaller. To make sure participants would use mental imagery to perform the size judgment task, actual and proposed sizes needed to be close. As a consequence, for each item, to compute the larger and the smaller estimates, we added or subtracted 1/3 of the mean rated size. In the size judgment task, we expected participants presented with the mean pretest size estimate plus 1/3 to generally respond "smaller," and expected participants presented with the mean pretest size less 1/3 to generally respond "larger." These were treated as normatively correct responses, and responses that violated them were discarded. For instance, the average estimated size for a lion was 5 feet 6 inches, the computed larger size was 7 feet 3 inches and the smaller size was 4 feet and 4 inches. In the size judgment task, an item was paired with a size larger than its actual size for half the participants, and with a smaller size for the other half.

Design and procedure

Thirty-two subjects participated in each of the study condition (imagery, perception). Within each group, half the participants were primed with list A and the other half with list B. The procedure in the perception and imagery study phases as well as the procedure in the filler task were identical to those in Experiment 1. This was a mixed design with Condition (imagery, perception) as a between-participants factor and Priming (studied, nonstudied) and Response type in the size judgment task (smaller, larger) as within-participants factors.

All participants performed the size judgment task after the filler task. Each trial began with an initial blank screen presented for 1,000 ms, followed by a fixation point for 500 ms and a second blank screen for 500 ms. Then a size in feet and inches was presented for 2,000 ms. The size was followed by a blank screen for 500 ms and by a word presented for 200 ms. The word was followed by a blank screen that ended with the participants' response.

Participants were instructed to decide whether the referent of the word was smaller or larger than the proposed size. They answered by pressing the appropriately marked button of the button box (assignment of the left and right buttons to the two responses was counterbalanced between participants). A feedback sound indicated whether participants answered correctly by either beeping (correct response) or buzzing (incorrect response). Response times were registered from the disappearance of the word. The test began with 16 training trials. Then, all participants were presented with the 80 items of the combined lists A and B, in random order. For each participant (either primed with list A or with list B), half of the items were studied and the other half were not. Half of the studied items required a "larger" answer and the other half a "smaller" answer. This was also the case for nonstudied items. Participants were not told that some items were repeated from study to test.

Results

Accuracy in the size judgment task was low ($M=69.55\%$, SD = 6%). A 2 × 2 ANOVA carried out on the percentage of correct responses with Condition and Priming as factors revealed no statistically main reliable effects or interactions, largest $F(1, 62)=1.54$, $P=0.22$.

A 2 × 2 × 2 ANOVA was carried out on response times for correct responses, with Condition (imagery, perception), Priming (studied, non-studied) and Response type (smaller, larger) as factors. Response times more than two SDs from the participant's mean for that condition were discarded. On average, 2.34% of latencies for correct responses were excluded.

In contrast to results of Experiment 1, in this analysis, the interaction of the factors Condition and Priming showed that priming from imagery was greater than priming from perception, $F(1, 62)=8.61$, $P<0.01$. In fact, as can be seen in Table 2, priming from perception was not present at all. The effect of priming was reliable in the imagery condition, $t(31)=2.77$, $P<0.01$, but not in the perception condition, $t(31)=-1.45$, $P=0.16$. These opposing trends led to the absence of an overall priming effect, $F(1, 62)=1.58$, $P=0.21$. Overall response times did not differ between the two groups, $F(1, 62)=0.21$, $P=0.65$.

Although this was not of main interest we explored the effect of the Response type factor. Overall, participants did not differentially respond to smaller ($M=1{,}337$ ms, SD = 510 ms) and larger trials ($M=1{,}308$ ms, SD = 545 ms), $F(1, 62)=2.77$, $P=0.10$. However, the priming and response type interaction [$F(1, 62)=5.39$, $P<0.03$] showed no priming for smaller trials, $t(63)=0.14$, $P=0.89$, but a trend for larger trials, $t(63)=1.89$, $P=0.06$. In fact, priming was statistically reliable for both larger trials, $t(31)=2.60$, $P<0.02$ (mean priming (nonprimed minus primed): 115 ms), and smaller trials, $t(31)=2.46$, $P<0.02$ (mean priming: 56 ms) in the imagery group, but did not reach significance neither for larger trials, $t(31)=0.23$, $P=0.82$ (mean priming: −7 ms), nor for smaller trials, $t(31)=1.97$, $P=0.057$ (mean priming: −61 ms), in the perception group. The trend, opposite to priming, that appeared for smaller trials in the perception group seems to have driven the significant interaction between priming and response type. Note that the interaction of the factors Response type, Priming and Condition was not significant, $F(1, 62)<1$.

Correct responses were defined relative to the size judgments of the pretest participants. These judgments are more subjective than the object identity judgments used in Experiment 1, and showed substantial interparticipant variability. As a result, "accuracy" (defined as agreement with the norm) was considerably lower than in Experiment 1 ($M=69.55\%$, SD = 6%). Therefore, we repeated the response time analyses including incorrect as well as correct responses. Results were the same as for the analyses reported here.

Table 2 Response time (in ms) for correct responses in the imagery and perception conditions of the size judgment task (Experiment 2) as a function of the priming factor (studied, nonstudied). SDs in parentheses

	Studied	Nonstudied
Imagery	1,250 (465)	1,336 (571)
Perception	1,370 (560)	1,335 (510)

Discussion

In this experiment, the same two study conditions used in Experiment 1 were combined with a test task that depended on retrieval and image generation processes. As predicted, the Priming × Condition interaction showed that priming was greater from imagery than from perception (where no priming was observed). Thus, the same two study conditions were shown to produce different patterns of priming, depending on the test task used.

This result replicates Wippich et al.'s (1989) and Cabeza et al.'s (1997) results and extend them to a different task and a different type of visual materials. In contrast, it is not consistent with results from Stadler and McDaniel's (1990) study, in which they failed to find a reliable difference between priming from perception to imagery, and from imagery to imagery. This new result tilts the balance in favor of the conclusion that tasks depending on image generation processes are better primed by an imagery study task than a perceptual study task.

General discussion

The results of this study can be summarized as follows. For a word-picture matching test task (Experiment 1), priming from imagery was weaker than priming from perception, replicating previous results. Priming from imagery did not reach statistical significance. In contrast, for a size judgment test task (Experiment 2), priming from imagery was greater than priming from perception. In fact, priming from perception was absent.

Previous priming studies consistently showed weaker priming from imagery than from perception (McDermott & Roediger, 1994; Roediger et al., 1992; Schacter & Graf, 1989; Stadler & McDaniel, 1990). There are two ways of explaining such a priming difference. First, one may argue that imagery activates visual representations to a lesser extent than perception (Stadler & McDaniel, 1990). Alternatively, one may emphasize the fact that imagery and perception not only share processes but also activate unique processes. As a consequence, the relative amount of priming obtained from imagery may depend on the type of processes involved in the criterion test (Cabeza et al., 1997; Michelon & Koenig, 2002).

The finding in Experiment 1 is consistent with either explanation. In this experiment, we used a word-picture matching task with a long inter-stimulus interval as the test, because under such conditions response time appears to depend primarily on processing the visual properties of the target picture (Scheerer-Neumann 1974). In the terms of Kosslyn's (1994) model, speed of responding in such a task depends primarily on a bottom-up processing stream leading from the visual buffer to the pattern activation systems via pre-processing. The greater priming observed from perception in this case can be attributed to the fact that the perception study condition relies differentially on this pathway, that is on the bottom-up processing of a visual stimulus.

The finding in Experiment 2 supports the view that weaker visual activation is insufficient to explain all visual priming from imagery. In Experiment 2 we used a size judgment test task because we hypothesized that participants would perform the task by retrieving visuospatial features of the objects from memory. In terms of Kosslyn's (1994) model, this requires retrieving a representation from associative memory, looking up coordinate and categorical properties, and activating a visual pattern. The greater priming observed from imagery in this experiment is thus attributable to the fact that only the imagery study condition relies on the same components as the size judgment task, that is on the top-down activation of object properties.

Priming effects have been explained as resulting from two qualitatively different forms of processing: conceptually driven and data driven (Blaxton 1989; Jacoby 1983). In this view, an imagery study task may be considered as a conceptually driven task, because the hypothesized analog representation bears no surface resemblance to the cue (a word), and the response required is not directly available in the stimulus (Blaxton 1989). In the present study, if the perceptual study task is classified as data driven, whereas the imagery study task is classified as conceptually driven, and the word-picture matching test task is classified as data driven, whereas the relative size test task is classified as conceptually driven, the explanation of this view is equivalent to the one we have advocated here. However, in this case it is not clear that this classification is justifiable *a priori*, and without it the account is circular. By specifying the processing resources involved at a finer grain we have attempted to avoid such circularity.

The current evidence that components of imagery not shared with perception can contribute to priming has important implications for the interpretation of other studies of priming from imagery. In the present case, the demonstration of conditions under which priming from imagery is greater than priming from perception was important for testing the hypothesis that priming from imagery can be driven by processing components not shared with perception. However, even in cases in which imagery produces less priming than perception, there is no guarantee that the same processes are driving priming from imagery and priming from perception. A stronger case can be made if the two kinds of priming are modulated by the same control variables, a condition that is rarely satisfied.

In conclusion, our results support the view that imagery is more than a weak reactivation of perceptual processes. Although imagery and perception share processes, both activities also engage specific processing systems. As a result, the two can have qualitatively different consequences for later memory.

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