Facilitation of length discrimination using real and imaged context frames

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In the first experiment we showed that difficult length discriminations can be facilitated by imagining a visual context frame that serves to emphasize small length differences between pairs of horizontal and vertical lines. This facilitative effect of imagery cannot be attributed to response-bias or expectancy effects because we have separated the object to be imagined from the objects to be discriminated. In the second experiment we showed that real context facilitates the line-length discrimination in much the same way as imagined context does. The results from these experiments suggest that (a) functional interactions can occur between imagery and perception at feature-processing levels of the visual system, and (b) there is a functional equivalence between the imagination and perception of helpful context. Results of a third experiment suggest that although imagery and perception may be functionally equivalent at the levels of visual processing where parts of patterns are combined, they are not functionally equivalent at the lower levels of simple detection.

Visual comparison tasks have frequently been used to demonstrate the practical functions of mental imagery. For example, a number of studies have shown that discrimination between a pair of objects can be facilitated when one of the objects is imagined in advance (Glushko & Cooper, 1978; Posner, Boies, Eichelman, & Taylor, 1969) or when one of the objects is mentally rotated into alignment with the other (Cooper & Shepard, 1973; Shepard & Metzler, 1971). Because the mental images that are formed in these studies typically correspond to one of the possible target objects (and hence to one of the possible responses that subjects could make), it is difficult to specify the precise level of information processing at which mental image formation facilitates visual comparisons. Such facilitation could be restricted to levels where response selection occurs or, conceivably, could occur at more peripheral levels where visual information about objects is processed before responses are selected. Ideally, one would like to find evidence for the facilitation of object discrimination in cases where mental images could not function merely to prime one of the response alternatives.

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It has been shown that object discrimination can be facilitated, independent of biases in response selection, when certain kinds of visual context patterns are presented. Williams and Weisstein (1978) found that diagonal line segments could be discriminated more accurately when presented together with a context pattern that defined a unitary three-dimensional form than when presented alone, even though this pattern provided no useful information about which particular line segment was more likely to appear. Similarly, Pomerantz, Sager, and Stoever (1977) found that presenting helpful visual context patterns could result in more rapid discriminations among various types of simple features (such as straight and curved line segments) even though the context patterns in no way suggested that any given feature was more likely to appear on any of the trials. These findings indicated that presenting appropriate context patterns may result in the activation of "higher order" feature detectors sensitive to the combined presence of target and context displays and, therefore, that context information can facilitate discrimination judgments by enhancing relevant differences between target objects in a bias-free manner. Accordingly, if it could be shown that object discrimination can be facilitated when similar types of helpful context patterns are merely imagined, one could reasonably claim that the facilitative effect of imagery occurs prior to the level of response selection.

The use of mental imagery to provide helpful contexts has already been investigated to some degree. To explore the possible effects of imagining context patterns on identifying visual target objects, Peterson and Graham (1974) instructed subjects to imagine visual scenes that were either compatible or incompatible with the objects. For instance, the subjects were instructed to imagine that they were seeing a spoon covered with ants in a picnic setting and were then shown a picture of a spoon or of some other object that would not fit so easily into that scene. The target objects were identified more accurately when compatible visual contexts were imagined than when no context scenes at all were imagined and were identified less accurately when incompatible contexts were imagined. The implication of these results was that imagined visual contexts can be helpful in distinguishing among a set of target objects; however, because the context patterns used by Peterson and Graham were related thematically to the targets, this facilitation could have been due to their subjects having had expectations about which targets were more likely to be presented on a given trial, as opposed to a strictly perceptual enhancement of the visual discrimination process.

The experiments we report in the present study reveal that difficult length discriminations can be facilitated by imagining a simple visual context frame that serves to emphasize small length differences between pairs of horizontal and vertical lines. The facilitation we demonstrate using this type of imagined context pattern cannot be attributed to response selection or expectancy effects, but rather suggests that imagery may interact directly with the perceptual processing of information about visual features to make those features easier to distinguish.

EXPERIMENT 1

To the extent that a mental image is functionally equivalent to the perception of a real object or pattern, it should be possible to find cases where images and perceptions are combined by the mind within one single representation. Thus, given that certain perceptual discrimination tasks have been shown to become easier with helpful real context stimuli (e.g., Pomerantz, Sager, & Stoever, 1977; Williams & Weisstein, 1978), we hypothesized that those discrimination tasks should become easier with helpful imagined context stimuli as well.

For our discrimination task we used a "test cross": two lines were presented simultaneously, one aligned vertically and the other horizontally, with each crossing through the center of the other. The subjects' task was to decide which line was longer. For the helpful context we asked subjects to image a "square frame" of a size we picked to emphasize the line-length differences in the test cross. For purposes of control, explained below, we also asked subjects to image an "X frame" that was designed not to be helpful in detecting line-length differences. Figure 1 displays the effect of combining real

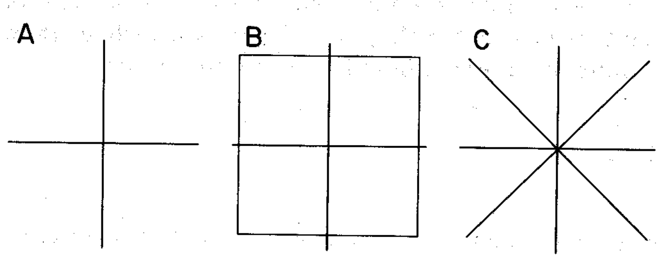

Figure 1. Effect of context frames (lines have been thickened for purposes of illustration): (A) test cross alone; (B) test cross with the helpful square frame superimposed upon it; (C) test cross with the unhelpful X frame superimposed upon it

context frames with the test cross. (Figure 1 is presented to allow the reader to get an intuition about the effect of context frames on the test cross; thus we have shown the real context superimposed upon the test cross. In our critical conditions of Experiment 1, we asked subjects to form an image of the context immediately *before* seeing the test cross.)

The dependent variable in Experiment 1 was reaction time for correct responses on the length discrimination task. The first comparison was between cases where subjects were instructed to imagine a helpful context frame before the length discrimination task and cases where subjects simply saw a central fixation point and formed no mental image. We predicted that subjects would react faster when they had formed the helpful image than when they had formed no image at all.

To ensure that subjects would be able to form a context image that was precise enough to be helpful, we presented four "corners" consisting of four equally spaced dots, which the subjects used to anchor the image in the correct place. To control for the possibility that a difference between conditions could be caused merely by the presence of the four corners, we also included a condition in which the four corners were used by the subject to anchor an *unhelpful* image. This condition also controlled for the possibility that the instructions to form an image might encourage subjects to attend more or try harder in the subsequent line-length discrimination task. Our second planned comparison was between cases where subjects imagined a helpful context frame and cases where they imagined an unhelpful context frame, with the expectation that they would take longer with the unhelpful context frame.

Finally, we included a fourth type of trial in which we presented the four corners with instructions to form no image. We were curious to see if subjects would treat this case as a "fixation-point-only" trial type or whether they would spontaneously form images of helpful context frames anchored on the four corners.

METHOD

Subjects

Subjects were 17 Stanford University undergraduates; 5 received course credit and 12 were paid for their participation.

Apparatus and stimuli

A Megatek 5000 graphics display screen, controlled by a Data General Nova computer, was used to present the stimuli. The Megatek screen had a

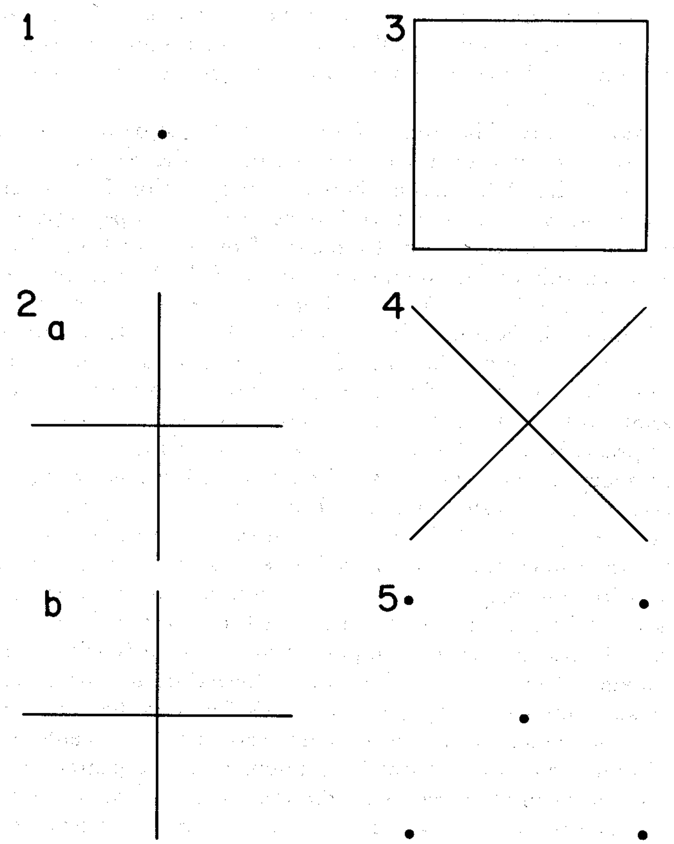

Figure 2. Basic stimulus forms (lines have been thickened and the fixation point and imagery corners have been enlarged for purposes of illustration): (1) fixation point; (2) test crosses; (a) vertical longer, (b) horizontal longer; (3) square frame; (4) X frame; (5) imagery corners

light-on-black display with a high resolution. Attached to the Nova were a two-key response board and a foot pedal used by the subject to initiate each trial. For all of the conditions in this study, only five basic stimulus forms were used, although they appeared in different orders and combinations. So that we can later refer to the stimulus displays by name, they are labeled and described here. They are also depicted in Figure 2.

1. Fixation point. A single grid point in the center of the screen was illuminated at full intensity to provide a fixation point.

2. Test crosses. Line-length discrimination stimuli always consisted of a vertical and horizontal line being shown simultaneously and at full intensity, with each passing through the center of the other. This "cross"

display was thus symmetric about both the horizontal and vertical axes as were all other visual stimuli in this experiment. Either the vertical or the horizontal line was longer by a small amount. The ratio of the shorter to the longer line was 29:30.

3. Square frame. The square frame, intended to be the helpful frame, was simply the outline of a square centered on the screen with its sides parallel to the sides of the screen, shown in full intensity. The dimensions of the square frame were such that when a test cross was superimposed upon it each limb of the cross extended outside of the square frame by a small amount. Each side of the square was 26/30 of the longer line in the test cross, or equivalently, 26/29 of the shorter line in the test cross.

4. X frame. The X frame, intended to be the unhelpful frame, was constructed by centering two full-intensity diagonal lines on the center of the screen such that they formed right angles with each other and were each at a 45° angle to the side of the screen. The end points of these lines corresponded precisely to the "corners" of the square frame.

5. Imagery corners and visually presented imagery instructions. Imagery-corners consisted of four full-intensity dots centered around the central fixation point and placed exactly at the four corner positions defining either the square frame or the X frame. It was thus possible to use the corners, with appropriate imagery instructions, as "anchor" points for forming mental images of either the square frame or the X frame. In some conditions the imagery corners appeared simultaneously with visually presented imagery "instructions." This was achieved by placing a very small, low intensity, but visible, square frame or X frame in the upper righthand corner of the screen while the corners were displayed centered on the screen. In other conditions a small low-intensity "no" appeared in the upper righthand corner of the screen with the four corner dots. As described below, subjects were instructed to treat the small frames as instructions to image the appropriate frame anchored on the four imagery corners, and to treat the word "no" as instructions to form no image.

Procedure

Subjects were tested individually. They were each asked to complete a practice program that familiarized them with the line discrimination task, and also an imagery training program, before being tested in the critical "imagined context frames" program.

Practice program. Subjects were instructed to begin each trial in the practice program by focusing on a central fixation point on the Megatek screen, and to rest their index fingers on the two response keys in front of them. To indicate that they were ready for the test stimulus, the subjects pushed down on a foot pedal. At that time, a test cross appeared and they were instructed to determine, as rapidly as possible, whether the vertical line or the horizontal line was longer. (Subjects were urged not to sacrifice accuracy by going too quickly, since the task was very difficult.) Responses were indicated by pushing the righthand key for vertical or the lefthand key for horizontal. There were 72 trials. For one third of the trials the cross appeared alone, for another third the cross appeared with a square frame superimposed upon it, and for the remaining third of the trials an X frame was displayed with the cross. In half of the cases for each type of test stimulus (cross alone, cross with square frame, or cross with X frame), the horizontal line was longer. The order of the 72 trials was randomized for each subject.

Imagery training program. It was explained to the subjects that the imagery training program collected no data and was for their benefit only. Furthermore, they were told that they should only continue with the program until they were confident of their ability to easily form the appropriate mental images. Subjects were verbally instructed to always form mental images using the imagery corners that they would see on the screen as anchor points. They were told that if the four imagery dots appeared with a miniature "square" in the upper righthand corner, they were to imagine a "large square" that used the four dots as corners. Similarly, if a miniature "X" appeared in the upper righthand corner, they should imagine a "large X" passing through the central fixation point and ending on each of the four dots. (The word "frame" was never used when speaking to subjects.) When the subjects clearly understood these instructions, they were allowed to begin the training program, which consisted of an equal, randomly ordered mixture of square-frame and X-frame trials.

Each trial began with the imagery corners presented along with either the square-frame instructions or the X-frame instructions. When the subject felt a good image of the appropriate frame had been formed, the foot pedal was to be pressed. The imagery corners were then replaced by the true frame, so that the subject had immediate feedback with which to compare the vividness and accuracy of the image. To start the next training trial, the subject pressed one of the response keys. After 10 to 20 trials, all but one subject announced that they were confident of their ability to form both images. (This particular subject claimed that he could not form images after 40 training trials, so we did not use his data.)

Imagined context frames program. After completing the imagery training program, subjects were told that in the final program they would be asked to make line-length discriminations as in the practice program and to form mental images as in the training program. Subjects were instructed to form the appropriate image whenever they saw the four dots presented together with the imagery instructions. When their image was formed they were to press the foot pedal, at which point the test cross would appear alone. Then they were to determine which line was longer and to respond using the response keys below their index fingers as in the practice program. Subjects were also told that for half of the trials they should form no image before the line-length discrimination. The no-image cases would be apparent because subjects would either be shown the word "no" along with the four dots instead of imagery instructions or they would be shown only a central fixation point. Finally, subjects were encouraged to take their time

forming images, or not forming images, as instructed, but to respond as quickly as possible when making the line-length discriminations. After any questions were answered, the experimenter let the subject begin the experimental program, which consisted of 128 trials.

One quarter of the test trials were preceded by the fixation point only; one quarter were preceded by the imagery corners and the square-frame instructions; one quarter were preceded by the imagery corners and the X-frame instructions; and one quarter were preceded by the imagery corners and the word "no." For each of the four trial types, half of the test crosses consisted of a longer horizontal line and half a longer vertical line. Thus the correct response in the discrimination task was completely orthogonal to the imagery instructions preceding the test cross.

RESULTS AND DISCUSSION

The results of Experiment 1 confirmed our prediction that an imagined helpful context would lead to faster reaction times in a subsequent line-length discrimination than either a fixation point alone or an imaged unhelpful context. Figure 3A displays the mean correct response times in each condition for the 14 subjects who showed error rates below our cutoff point of 25%. Each of the two planned comparisons revealed significant differences using one-tailed tests. Trials in which subjects formed images of the helpful context were responded to faster (by 388 ms) than when only a fixation point appeared, $t(13) = 2.08$, $p < .05$. Similarly, trials in which subjects formed images of the helpful context were responded to more quickly (by 234 ms) than trials in which they formed images of the unhelpful context, $t(13) = 1.87$, $p < .05$.

That the line-length discrimination task was very difficult was indicated by the relatively long reaction times and high error rates. Mean error rates for the 14 subjects who showed individual rates of 25% or lower were, by condition, 10% for fixation point only; 12% for square-frame image condition; 15% for X-frame image condition; and 11% for "no" image condition. Neither of our planned comparisons applied to these error data was significant, ruling out a speed/accuracy tradeoff explanation of the significant reaction time results. Furthermore, the error data for the comparison we were most interested in, that between the X frame and the square frame, were consistent with the reaction time data: Both results suggest the line-length discrimination task is easier in a square-frame context than in an X-frame context. However, the error data suggest that the X-frame condition was more difficult for subjects than the fixation-point-only condition, whereas the reaction time data suggest the opposite result. It is therefore unclear in Experiment 1 whether

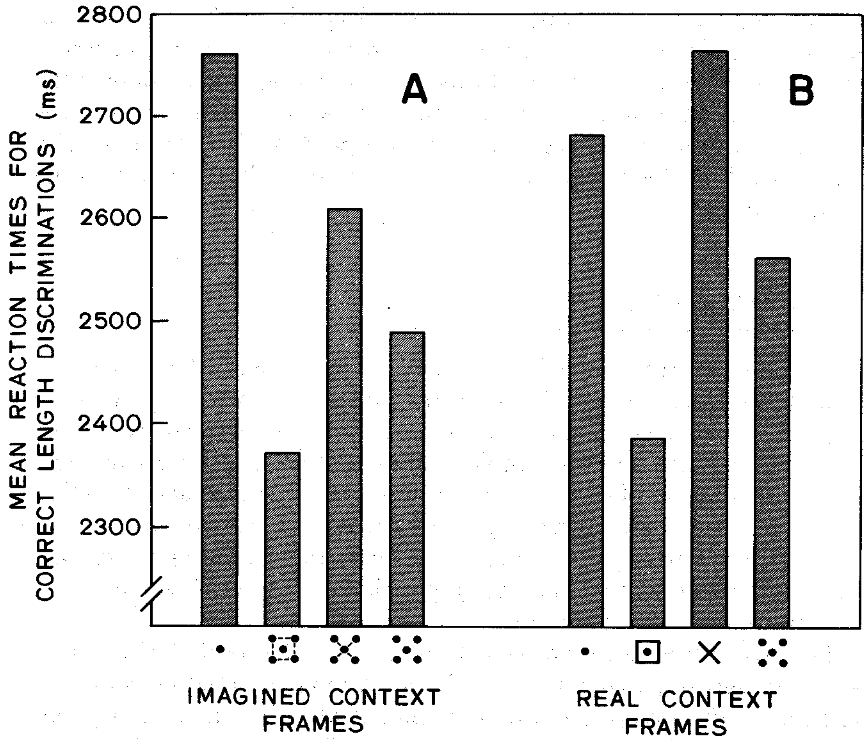

Figure 3. Mean discrimination times (A) in Experiment 1, where context frames were imagined; (B) in Experiment 2, where context frames were actually presented (for each experiment, $N = 14$)

the X-frame condition was unhelpful as compared with the fixation-point-only condition. It is clear, however, that the X-frame condition was unhelpful as compared with the square-frame condition.

The fourth condition, in which the four imagery corners appeared with the word "no," produced reaction time data suggesting that subjects spontaneously imaged the helpful square frame at least part of the time. This seems relatively probable, given that they had been drilled on responding to the four corners by forming an image. It would therefore be useful to know how subjects perform with the four corners when they had no imagery instructions or imagery training. This was, in fact, one of the questions we attempted to answer in Experiment 2.

The main results from Experiment 1, that an imagined helpful context frame facilitates performance in a line-length discrimination task as compared with forming no image or with forming an unhelpful image, are very encouraging for our hypothesis that images and perceptual stimuli can be combined mentally into a single representation. A second question that emerged, however, was whether the imaged context frames interact with perceptual stimuli in the same way as real context frames interact with perceptual stimuli. In Experiment 2 we looked for evidence of this hypothesized functional equivalence.[1]

EXPERIMENT 2

The results from Experiment 1 are consistent with the hypothesis that mental images can facilitate discrimination of real perceptual objects. Furthermore, these results cannot be explained by the alternative explanation applicable to most previous attempts to show image facilitation of discrimination, that the mental images function merely to prime one of the response alternatives. However, it would be more convincing if we could show that mental images facilitate the discrimination in a manner equivalent to the facilitation of the discrimination by real contexts.

Following the argument (see Finke, 1980; Shepard, 1978; Shepard & Podgorny, 1978) that functional equivalences between mental imagery and perception can be demonstrated in experiments that show that mental images of objects have effects similar to those that occur when objects are actually observed, we designed Experiment 2 to be the perceptual analogue of our imagery study, Experiment 1. That such an equivalence *should* be found in the present case is suggested especially by studies demonstrating that mental images of simple line patterns can produce orientation-contingent color aftereffects (e.g., Finke & Schmidt, 1977), can show decreasing visual resolution with the decreasing pattern size and increasing peripheral extent (e.g., Finke & Kurtzman, 1981), and when forming an enclosed figure, may be attended to in the same manner as actual physical patterns (e.g., Podgorny & Shepard, 1978). Each of these findings provides evidence that imagined and observed patterns can be functionally equivalent specifically at feature-processing levels of the visual system.

In Experiment 2 we used four conditions based on those of Experiment 1. One condition was exactly the same, the case where a fixation point preceded the test crosses. For the second condition, we replaced the imagery corners and square-frame instructions with an actual square frame. For the third condition, we replaced the imagery corners and the X-frame instructions with a true X frame. Finally, for the fourth condition, we left the imagery corners but removed the "no" imagery instructions. We predicted that we would find the same pattern of results as we found in Experiment 1 for the first three conditions. In addition, we expected the reaction time to increase in the fourth condition in Experiment 2 as compared with Experiment 1, because there would be less reason for subjects to spontaneously form helpful images when presented with the imagery corners without explicit imagery training.

METHOD

Subjects

A new group of 17 Stanford University undergraduates participated in this study. All received course credit for their participation.

Apparatus and stimuli

The apparatus and stimuli of Experiment 2 were the same as those for Experiment 1 except that we did not use the visually presented imagery instructions.

Procedure

Subjects were again tested individually. They were each asked to complete a practice program that familiarized them with the line discrimination task, and were then asked to complete the critical "real context frames" program.

Practice program. Subjects were administered the same practice program described in the method section of Experiment 1.

Real context frames program. After completing the practice program, subjects were told that in the next program they would be asked to make the same kind of line-length discriminations. They were also told that the fixation point might appear with either a "large square," a "large X" passing through it, or with "4 dots" surrounding it. Subjects were instructed to indicate that they were ready for the test stimulus by pushing down on the foot pedal. At that time a test cross appeared by itself, and they were instructed to determine, as rapidly as possible, whether the vertical line or the horizontal line was longer. After any questions were answered, the subject initiated the experimental program, which consisted of 64 trials.

One quarter of the test trials were preceded by the fixation point only; one quarter were preceded by the square frame; one quarter were preceded by the X frame; and one quarter were preceded by the imagery corners (in this case with no imagery instructions). For each of the four trial types, half of the test crosses consisted of horizontal line longer, and for the other half, vertical line longer. Thus, as in Experiment 1, the display preceding the test cross was completely orthogonal to the correct response in the discrimination task. The order of the 64 trials was randomized for each subject. Reaction time and accuracy were recorded as in Experiment 1.

RESULTS AND DISCUSSION

The pattern of results from Experiment 2, which revealed perceptual facilitation, was consistent with that obtained in Experiment 1, which revealed imagery facilitation; thus, the results of the two experiments taken together are consistent with the functional equivalence hypothesis. This consistency is shown in Figure 3, parts A and B. Part B displays the mean correct reaction times in each condition for the 14 subjects who showed error rates below the 25% cutoff. Corresponding to the results of Experiment 1, the trials in which subjects saw the helpful context were responded to significantly faster (379 ms) than those in which they saw the unhelpful context, $t(13) = 2.03$, $p < .05$ (one-tailed). Similarly, the trials in which they saw the helpful context were responded to more quickly (by 294 ms) than those trials in which they saw only a fixation point before the test cross, although this difference did not reach significance, $t(13) = 1.23$.

The correspondence between the reaction times in the two experiments was further shown using a single two-way analysis of variance on the combined data, in which the between subjects factor was whether the context was real or imagined, and the within subjects factor was the four types of context frames. Because this combined analysis gave us greater statistical power, we were able to use two-tailed tests of significance. The results of that analysis were as expected: There was no main effect for whether the context was real or imagined ($F < 1$) and no interaction between whether the context was real or imagined and type of context ($F < 1$). There was, however, the expected main effect for type of context frame, $F(3, 78) = 3.80$, $p < .025$, and the specific comparison between the square-frame and fixation-point-only trials was significant, $F(1, 78) = 8.99$, $p < .01$, along with the comparison between the square-frame and the X-frame trials, $F(1, 78) = 7.194$, $p < .025$.

In Experiment 2, subjects again found the line-length discrimination task to be difficult, as indicated by their long reaction times and high error rates. The mean error rates for the 14 subjects who showed individual rates of 25% or lower were, by condition, 13% for fixation point only; 12% for square-frame trials; 13% for X-frame trials; and 14% for the four corners. As in the previous experiment, there were no significant error effects, again ruling out a speed/accuracy trade-off explanation of the reaction time differences.

Although the mean reaction times for subjects in both experiments are very similar across conditions and almost exactly the same for the imaged square frame as for the real square frame, there is a tendency in the data suggesting that the real X frame is more distracting than the imagined X frame for the line-length discrimination. One possible explanation for this is that in the imagery experiment some of the subjects might not have formed images as vivid as their perceptions of the real context patterns. However, given that the square frame seems to have been equally facilitative for the two groups, this explanation is problematic. Conceivably the reaction time difference for the X-frame effects might have occurred because some subjects in Experiment 1 were not inclined to perform the work of imagining an unhelpful context. Although few subjects when questioned after the experiment acknowledged conscious awareness of an effect of the imaged frame on ease of the line-length discrimination, it is still possible that at some level they might have had knowledge about helpful contexts. This account is very speculative, of course, but it does suggest the interesting possibility that images that facilitate performance on visual tasks may sometimes be formed spontaneously. It may be that the mind is naturally willing to add context to visual features so as to "construct" higher order visual patterns useful for more efficient processing of feature information. Also relevant to this issue are the reaction-time data from the fourth condition in each experiment, where the test trial was preceded by the four corners with the "no" imagery instructions in Experiment 1, and by the four corners alone in Experiment 2. One explanation for the small difference between response times for the fourth condition in the two experiments is that subjects spontaneously formed images of the helpful context more often in Experiment 1 than in Experiment 2. Because they had not been trained to do so, it is less likely that subjects in Experiment 2 would have formed such images, although it is possible that the four corners suggested the outline of a helpful context square to a few of them.

One concern that might be raised about Experiment 2 is that the context was never presented simultaneously with the test cross; thus, in effect, the "perceptual context" facilitation of the line-length discrimination might have worked via an icon or some more abstract form of visual memory that persisted after the context stimulus had disappeared and during the period when the test cross was presented. It could, for instance, be claimed that what we really showed is a functional equivalence between a perceptual icon and an image icon. To ensure that the imagined context frames were truly functionally equivalent to physically present context frames, we later asked the subjects from Experiment 2 to complete an additional short program in which the context frames were shown simultaneously with the test cross. For trials with only the fixation point, the

average reaction time was 2,552 ms; for square-frame trials it was 2,485 ms; and for X-frame trials it was 2,929 ms. The corresponding error rates were 14%, 9%, and 15%. The only significant difference among the reaction times is that between the square-frame and X-frame trials, $t(14) = 2.21$, $p < .05$. The results are consistent with our prediction that the square-frame context would be more helpful than the X-frame context in the line-length discrimination task even when presented together with the test cross. That the square-frame context was not much better than no context at all in this case suggests that there is some tradeoff between the facilitation effect of the frame and the time lost due to the extra visual processing required to see the frame. However, superimposing the actual frame did result in the lowest error rate, suggesting that although some additional time is required to process the frame when presented simultaneously with the test cross, accuracy in discriminating line length is increased. When the frame is presented (or imagined) in advance, the facilitative effect in reaction time is obtained, because subjects then have the opportunity to process the context information before the test cross is presented.

In summary, the main results of Experiment 2 replicate those found previously in Experiment 1 using imagined context stimuli. This predicted congruence between the two experiments lends strong support to the hypothesized functional equivalence between mental imagery and perception. Not only does imagery facilitate a line-length discrimination (as in Experiment 1), it does so in a manner consistent with a real-context facilitation (as in Experiment 2). In addition, because in each case the probability of any given response being correct was designed to be totally independent of the type of context used, response priming explanations of the context effects can be ruled out.

EXPERIMENT 3

We have argued that previous evidence for the imagery facilitation of object discrimination is subject to the alternative explanation that images function merely to prime one of the response alternatives. In Experiment 1 we found an imagery facilitation effect that could not be attributed to response bias. In doing so, however, we did not look for evidence for the specific sort of facilitation for which other investigators have looked; we did not show that discrimination among pairs of objects is facilitated when one of the *objects* is imagined in advance. In principle, the strongest sort of imagery facilitation of perception one could find would be where imagining an object in advance actually reduces the amount of time or effort required to process purely perceptual information about the object. This has been, in fact, what many investigators have claimed to have shown by finding an imagery facilitation of discrimination.

In Experiment 3 we looked for evidence that imagining a pattern in advance facilitates the perceptual processing of that pattern itself. This is thus a test of the strongest facilitation hypothesis, because the pattern being imagined corresponds to the pattern that is actually presented. The experimental design we used in Experiment 3, however, has the advantage of separating the pattern to be imagined from the patterns to be discriminated. We achieved this separation by using context frames as the patterns to be imagined *and* as the patterns presented, while using a test cross for the discrimination task. That is, the context frames were imagined in advance and presented simultaneously with the test crosses. The logic was that if imagery facilitates perceptual identification, then subjects should be faster to process the helpful frame after they have just formed an image of it, and thus faster to use it in the line-length discrimination task, than when they had not formed an image of the helpful frame.

METHOD

Subjects

The same group of 17 Stanford undergraduates used in Experiment 2 participated in Experiment 3 after they had been in Experiment 2.

Apparatus and stimuli

The apparatus and stimuli of Experiment 3 were the same as those for Experiment 1.

Procedure

Subjects were first given an imagery training program and then asked to complete an "imagined context preceding real context program." Because these subjects were first used in Experiment 2, they were already familiar with the line-length discrimination task.

Imagery training program. Subjects were administered the same imagery training program as described in the method section of Experiment 1.

Imagined context preceding real context program. Subjects were given the same set of instructions for the present program as for the "imagined context frames program" used in Experiment 1, with the one exception that there was no need to instruct them about no-imagery central-fixation-point trials, as all no-imagery trials were indicated by the four dots with the word "no." After any questions were answered, subjects began the experimental program, which consisted of 128 trials. For half of the test trials, the square frame was superimposed on the test cross and for the other half the X frame was superimposed on the test cross. An orthogonal factor was whether subjects formed an image of the context frame before the test cross appeared. There were thus four types of trials: One quarter of the test trials consisted of a square frame superimposed on the test cross preceded by the imagery corners and the word "no"; one quarter consisted of an X frame superimposed on the test cross preceded by the four corners and the word "no"; one quarter consisted of the square frame superimposed on the test cross preceded by the imagery corners and the square-frame instructions; and one quarter consisted of the X frame superimposed on the test crosses preceded by the imagery corners and the X-frame instructions. For each of the four trial types, half of the test crosses consisted of horizontal line longer, and for the other half, vertical line longer. Thus, as in Experiments 1 and 2, the correct response in the discrimination task was completely orthogonal to the imagery instructions preceding the test cross.

RESULTS AND DISCUSSION

The results (Table 1) suggest that imagery does not facilitate perceptual identification itself. There were no significant differences between trials where imagery instructions preceded the actual helpful context and trials where imagery instructions did not precede the actual helpful context. The error rates, although lower overall than in Experiments 1 and 2 (presumably because subjects had more practice with the line-length discrimination task), were not significantly different between conditions. However, there was the usual difference between square frames and X frames; the X-frame trial discriminations took an average of 610 ms longer than the square-frame trial discriminations, $t(13) = 2.85$, $p < .05$. It seems, then, that although imagery and perception may be functionally equivalent at levels at which parts of patterns are combined, such as when a real test cross is combined with an imagined context frame, they are not functionally equivalent at the lowest detection levels (where, if they were, we would expect a facilitation due to imagery). This tentative conclusion appears to be consistent with the findings of several other

Table 1. Reaction time results (milliseconds) of Experiment 3

Condition	Context	
	Square frame	X frame
No imagery	2,126 (8%)	2,677 (16%)
Imagery	2,204 (7%)	2,920 (13%)

Note. Error rates in parentheses.

studies showing that simple detection judgments are not facilitated when a mental image of the object is formed in advance (Finke, submitted for publication) or when advance information about the shape of the object is provided (Posner, Snyder, & Davidson, 1980).

GENERAL DISCUSSION

The findings of Experiment 1 demonstrate that instructing subjects to form a mental image of a helpful context pattern in advance can facilitate simple length discriminations. This facilitation, moreover, seems to be equivalent to that obtained when actual context patterns are presented (Experiment 2). These findings have an important practical implication: When individuals know what kind of discrimination needs to be made, they can make that discrimination more quickly by forming an image that emphasizes differences between features of objects that are relevant to the comparison. In the present case, the square-frame image that subjects formed emphasized small differences between the lengths of a pair of lines; in general, it should be possible to construct similar kinds of images that would facilitate the discrimination of differences along other perceptual dimensions such as size and shape.

The results of Experiment 3, in contrast, suggest that imagery cannot easily facilitate the perceptual processing of the imagined object. Although other investigators have sometimes claimed that their studies provide evidence for just this kind of facilitation, it seems probable that such effects are artifacts of the particular discrimination tasks used. In particular, when one of the objects being imagined in advance is also one of the objects being discriminated, the facilitation could be due to response priming. When the objects being imagined are separated from the objects being discriminated, as in our Experiment 3, there is little evidence for imagery facilitation.

Notes

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[1]It is also important to consider alternative explanations for the results of this first experiment based on the way attention might have been allocated to the test cross as a consequence of the particular imagery instructions. For instance, the square-frame imagery instructions might have drawn the subjects' attention to two of the dots, one on each side of a line, in such a way as to make the line's length more noticeable. However, such an attention account, when carried to the limit, verges on an imagery account. That is, if people can allocate their attention so precisely that they can create thin bands of it corresponding to context patterns at particular locations in the visual field (which would be necessary to get a facilitation effect, because it is not enough to merely attend to the dots in different ways; rather, the attention must indicate how the dots are connected), then it is not at all clear how such a definition of attention differs from that of a mental image. Perhaps a more plausible alternative account is that when asked to imagine the square-frame pattern, subjects merely switched their attention back and forth between the ends of the horizontal and vertical lines, without forming images. Although attention switching of this sort would almost surely be used to interpret the context information (whether imagined or actually presented), it is not obvious how it would be helpful in the absence of such information. In any case, our subjects all reported that they had complied with the instructions and had formed the appropriate images as requested.

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