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Boundary Extension: Fundamental Aspect of Pictorial Representation or Encoding Artifact?

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Viewers remember seeing more of a scene than was actually depicted in a photograph, a phenomenon called boundary extension (H. Intraub & M. Richardson, 1989). We tested whether prior warning would eliminate this distortion, by having 81 Ss view 12 photographs of simple scenes for 15 s each after receiving 1 of 3 encoding instructions. All subjects were told to remember each picture in detail. Control Ss received no additional information. Test-informed Ss received prior warning about the type of tests. Demo Ss experienced a demonstration of the phenomenon and were instructed to guard against it. After presentation, a drawing task and a boundary recognition test were administered. Prior warning sometimes reduced, but never eliminated, boundary extension. We suggest the phenomenon reflects activation of scene expectations during perception.

When remembering a photograph, viewers tend to recall information that was not shown in the picture but that was likely to have existed just outside its boundaries. This unidirectional distortion of the picture space was first reported by Intraub and Richardson (1989), who referred to it as *boundary extension*. Intraub and her colleagues have reported that the phenomenon occurs both in subjects' drawings of remembered photographs (Intraub, 1992; Intraub & Richardson, 1989) and in tests of their recognition memory (Intraub, 1992; Intraub, Bender, & Mangels, 1992; Intraub & Richardson, 1989).

In several experiments, after viewing photographs for 15 s each, subjects almost always drew pictures with extended boundaries. This occurred when they viewed as many as 20 pictures followed by a 48-hr retention interval (Intraub & Richardson, 1989) or as few as 7 pictures tested immediately (Intraub, 1992). Subjects tended to reduce the size of the object in the picture space and to include more background information. The drawings depicted extended boundaries regardless of whether the main object or any background objects had been cropped by the picture's edges, thus indicating that the phenomenon was not simply a demonstration of the Gestalt principle of object completion (see Ellis, 1955). Subjects apparently recalled having seen more of the scene than had actually been presented.

This memory distortion was not limited to recall. It was clearly evident when recognition memory was tested. In these tests, subjects were required to rate whether the object in each test picture was the same, closer, or farther away than before on the following 5-point scale: (−2) *much too close*, (−1) *slightly too close*, (0) *the same*, (1) *slightly too far*, or (2) *much too far* (Intraub, 1992; Intraub et al., 1992; Intraub & Richardson, 1989). In some of the recognition tests, no distractors were presented. In these tests, subjects viewed the same pictures again and rated them on the scale. In other experiments, both the same pictures (targets) and distractors depicting either closer or wider views than the stimulus were presented. In both cases, when targets were presented, subjects tended to rate them as depicting closer views than before, thus indicting that their pictorial representation contained extended boundaries. In various experiments, this recognition error was obtained when memory for 7, 8, or 18 pictures was tested immediately (Intraub, 1992; Intraub et al., 1992) and when memory was tested for 18 or 20 pictures after a 48-hr delay (Intraub et al., 1992; Intraub and Richardson, 1989). Once again, the effect occurred whether or not any objects had been cropped by the pictures' boundaries, thus ruling out object completion as the cause of the distortion.

In recognition tests that included both targets and distractors, the responses made to the distractors provided additional evidence for boundary extension (Intraub et al., 1992; Intraub & Richardson, 1989). Two versions of the same scene were photographed, one a slightly wider angle version of the other. When the close-up version was the stimulus and the wider angle version was the distractor, subjects frequently accepted the distractor as being the same as the stimulus. When the wider angle version was the stimulus and the close-up version the distractor, such errors were rarely made. This asymmetry in false recognition responses, as well as in the mean ratings to the distractors (wide-angle distractors were rated as being closer to the *same* than were close-up distractors) indicates that wide distractors tended to match the subject's recollection better than did close distractors.

Tests of alternative explanations of boundary extension have provided support for what Intraub and her colleagues have called the *perceptual schema hypothesis* (Intraub, 1992; Intraub et al., 1992; Intraub & Richardson, 1989). The per-

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ceptual schema is a mental representation of the likely structure of the real-world scene that the picture only partially reveals. Activation of the schema allows the viewer to understand a picture within this larger context. The schema is thought to be similar to the abstract spatial representation proposed by Hochberg (1978, 1986) to account for the integration of successive views during visual perception; a representation he referred to as the *mental schema*.

Hochberg (1978, 1986) has argued that an abstract mental schema or map provides a context for interpreting partial views of the visual world. He has based his argument on an analysis of the viewer's ability to understand motion picture and video displays. Such presentations include rapid shifts of the camera's view (i.e., shifts that the observer could never make via his or her own locomotion). The ease with which an observer comprehends these shifts in viewpoint suggests the use of a mental schema within which successive views are analyzed and understood.

For example, Hochberg (1978, 1986) described an experiment in which subjects watched an animation depicting an outline cross moving behind a stationary circular aperture. When subjects were unaware of what the display was intended to depict, they often perceived it as depicting the face of a clock with rapidly moving hands. However, when they were provided with a long shot of the cross followed by a medium shot and then by a close-up, thus establishing that an outline cross was behind an aperture, their perceptions changed. Although the aperture never allowed the whole outline cross to be seen at one time, the subjects "perceived" its existence outside the boundaries of the circle. Their perception was accurate enough to allow them to recognize when one of the arms of the cross had been skipped. The same results were obtained when instead of providing any establishing shots, subjects were simply told that they would be viewing a moving outline cross through a circular aperture.

The point of this demonstration is that the viewer's visual perception in part depended on his or her mental schema of the whole scene, even when the whole scene (in this case the moving cross) was never visually presented in any single view. The schema, therefore, cannot be composed of a collection of prior views. It must be a more abstract representation. In research on the integration of eye fixations, Irwin, Brown, and Sun (1988) have argued that the repeated failures to obtain evidence for a spatiotopic icon suggests that integration of eye fixations may be mediated by an abstract, nonsensory spatial representation of this type. We propose that this representation may also underlie picture perception.

Just as the aperture in Hochberg's (1978, 1986) experiment prevents the subject from ever seeing the whole cross at once, we have argued that the boundaries of a picture prevent the subject from seeing an entire real-world scene at once. The perceptual schema provides expectations about what the next eye fixation would bring into view if a next eye fixation outside the picture's boundaries could actually be made. We argue that this expectation is such an integral part of picture perception that highly probable schematic information from the area just outside the scope of the picture becomes incorporated in the subject's mental representation, thus yielding boundary extension.

We have argued that if this hypothesis is valid, then the following two predictions should be verified as increasingly wide-angle views are presented. The first is that regardless of whether the main object fills the picture space (as in a close-up view) or covers a very small portion of the picture space (as in a wide-angle view), boundary errors should only involve extension; they should never involve restriction. The schematic expectations are always outward toward the expected area just outside the picture's boundaries. The second prediction is that as increasingly wide-angle pictorial views are presented, the degree of boundary extension should decrease.

This latter prediction is based on the assumption that the most predictive part of the schema is that area immediately surrounding an attended object. In a close-up, there is relatively little uncertainty about what is likely to exist just outside the picture's boundaries. In wider angle views of the object, more of the predictable area is represented within the picture itself. For example, consider a tight close-up of a cup on a tabletop. There is very little uncertainty that more of the tabletop exists just outside the boundaries of the picture. As wider angle views are presented, one is less certain about whether the edge of the table has been reached. This is true whether the background is a tabletop or a field of grass. Close-up views impart a greater sense of expectancy and would therefore be expected to yield a greater degree of boundary extension than would wider angle views of the same scene.

To test these predictions, Intraub et al. (1992) presented subjects with close up, prototypic, or wide-angle views of the same 18 scenes. When memory was tested within minutes, the results followed the predictions of the perceptual schema hypothesis. No picture type yielded boundary restriction, and the degree of boundary extension decreased as increasingly wide angle views of the scene were presented. When another group's memory was tested after 48 hr, however, although the close-up and the prototypic views were remembered with extended boundaries, the degree of extension decreased, and wide-angle pictures yielded a small degree of boundary restriction. Intraub et al. proposed a two-component model of pictorial representation to account for these results. They suggested that initially, perceptual expectations tend to push the boundaries outward, and then over time, normalization in memory toward the average view in the picture set affects the representation such that both extension and restriction may be observed. Subsequent research replicated the results of the immediate condition, using both drawings and recognition tests (Intraub, 1992), thus providing additional support for the perceptual schema hypothesis.

The possibility that boundary extension reflects such a fundamental aspect of picture perception is an exciting one but as yet remains speculative. It is quite possible that the phenomenon, although ubiquitous, is actually an artifact of a widely accepted encoding strategy. In all of the previous research, subjects were instructed to remember each picture in as much detail as possible, paying equal attention to the main object(s) and to the background. In spite of these instructions, subjects may have interpreted their task as trying to remember what was in each picture, instead of focusing on its layout within the picture space. When faced with the unexpected task of reporting (through drawings or ratings) the placement of the pictures' boundaries, they may have been forced to rely on inferences drawn from their knowledge about real-world scenes, thus pushing the boundaries outward.

The possibility that the subjects' encoding strategy might be the cause of boundary extension is supported by the literature. For example, Intraub and Nicklos (1985) have demonstrated that simply changing an orienting question from semantic (e.g., "Is this edible?") to structural (e.g., "Is this angular?"), results in improved free and cued recall of photographed scenes. They suggested that the semantic orienting questions may have been redundant with the subjects' usual focus on what is being depicted, whereas the structural orienting questions may have added to this usual focus, causing subjects to devote more attention to the unique physical characteristics of the pictures.

It has also been established that a mismatch between an encoding task and a subsequent memory test can adversely affect memory performance (e.g., Morris, Bransford, & Franks, 1977; Roediger & Challis, 1992; Roediger, Srinivas, & Weldon, 1989; Stein, 1978). The classic research conducted by Morris et al. is particularly relevant. In addressing the well-accepted semantic superiority effect associated with levels of processing experiments with verbal stimuli, they demonstrated that a semantic orienting task yielded worse performance than a rhyme orienting task when a rhyme test was administered but that the reverse occurred when a semantic test was administered but that the reverse occurred when a semantic test was administered. They argued that when the processing strategy matches the memory test, superior performance will result.

The subject's expectation about the type of test to be administered has also been shown to affect visual memory performance (Frost, 1972; Tversky, 1969; Weldon & Roediger, 1987). Using outline pictures as stimuli, Frost demonstrated that subjects' expectations about whether memory would be tested using verbal free recall or visual recognition affected their performance on both types of tests. Tversky showed that reaction time (RT) in a matching task in which outline faces or their names were presented, was affected by the subjects' expectations about whether the second stimulus of a pair would be a picture or a word. She argued that regardless of the modality of the fist stimulus, test expectation affected whether it was encoded visually or verbally. Similarly, in measuring priming effects, Weldon and Roediger have shown that the type of retrieval task (free recall or word-fragment completion) will determine whether pictures or words are superior as the prime.

The purpose of the present research was to determine whether, contrary to the perceptual schema hypothesis, boundary extension occurs because of the subjects' test expectations and encoding strategies. We attempted to affect encoding in two different ways. In the test-informed condition, prior to presentation, subjects were informed that they would be required to draw the pictures later and were given a detailed description of the boundary recognition test in which they would participate. In the demo condition, we had subjects take part in a boundary extension demonstration, and we instructed them to try to avoid this error when studying the picture set. The results of each condition were compared with those obtained in the control condition, in which subjects had received the typical instructions used in previous research. If boundary extension reflects a fundamental aspect of picture perception (i.e., activation of a perceptual schema), then it should persist, even when subjects attempt to remember boundary placement. If boundary extension reflects an encoding bias, then changing the subjects' implicit orientation from "What is this a picture of?" to "How much of the scene does this picture show?" should eliminate this unidirectional distortion of the pictures' boundaries.

In addition to instruction type, we included two other independent variables: picture type and distractor type. Picture type refers to whether or not the main object is cropped by the picture's boundaries. As described earlier, previous research has shown that boundary extension occurs for both types of stimuli. We included both types in the present study, because in conditions in which encoding instructions orient subjects to consider the boundaries, we reasoned that cropped pictures should be particularly resistant to boundary extension because cropping an object provides a relatively concrete marker for the location of a boundary. If the new orientation was to have an effect, we believed that this stimulus type would serve to enhance its effectiveness.

The other independent variable was distractor type. As described earlier, in previous boundary recognition tests, when distractors were included, picture pairs were used in which one picture was a slightly wider angle version of the other. Each picture served as the stimulus in one case and as the distractor in the other. Picture pairs were used because stimuli and distractors, by definition, differed by an equal amount from one another across presentation–test conditions. The problem with this procedure is that memory for the closer view could only be tested with a wider view and vice versa. To provide a balanced test procedure in which memory for each stimulus could be tested using both wider and closer distractor types, in the present research, we used *area within the picture space* as a metric for evaluating similarity of stimuli and distractors. A close distractor and a wide distractor for each stimulus picture were selected such that the object in the two distractors differed by the same percentage area from the object in the stimulus. On average, our close distractor objects were 25% larger, and our wide distractor objects were 25% smaller than the stimulus object. Replication of the asymmetrical response to distractor types in conditions yielding boundary extension would validate the new test procedure.

Finally, because encoding instruction might have a differential effect on recall and recognition, we administered a free-recall test (drawings) followed by a recognition test. If boundary extension were to persist in the drawings (perhaps because of the inferential nature of recall), we wanted to determine whether it would be eliminated under conditions in which the subjects actually viewed the pictures again. For those subjects who had received boundary-relevant encoding instructions, reestablishing the initial encoding context (by presenting the test photographs) might result in an elimination of boundary extension. In evaluating the recognition test results, it is important to note that prior research showed that the introduction of a drawing task prior to the boundary recognition test, had no effect on boundary recognition scores (Intraub & Richardson, 1989). Apparently, subjects' interactions with their own drawings (which had extended boundaries) did not cause an increase in boundary extension on the recognition test: Boundary scores were virtually identical, regardless of whether drawings had been made. We therefore considered it worthwhile to use both means of testing memory in assessing the effects of the new encoding instructions.

Method

Subjects

Subjects were 81 University of Delaware undergraduates (41 of whom were women) who had agreed to participate in the departmental subject pool for an introductory psychology course.

Apparatus

Subjects were seated in three rows of three seats each, centered in front of a rear-projection screen. Slides were presented using one channel of a three-channel projection tachistoscope, with UniBlitz shutters and shutter drives (Model SD-122B). Image size was 17 in. × 26 in. (43 cm × 66 cm). The approximate visual angles were 13° × 20°, for a subject sitting in the front-row center, and 6° × 9° for a subject sitting in the rear-row center.

To analyze the drawings, we used an Intel 386 25 mHz International Business Machines (IBM) compatible computer equipped with a 4 megabyte AtVista graphics board. Pictures were digitized using a Japan Victor Corporation (JVC) color video camera. A Mitsubishi color monitor was used to display digitized drawings for analysis (see *Area Measurement* section).

Stimuli

There were 12 photographs (35-mm slides) that served as stimuli. Each depicted a main object against a relatively homogeneous natural background (see Appendix A for descriptions). For each of these there were two types of distractors: a close distractor and a wide distractor. On average, the main object in the close distractor was about 25% larger than in the stimulus photograph, and the main object in the wide distractor was about 25% smaller than in the stimulus photograph. One scene in each trio had been rated as either a close-up or prototypic view in previous research (Bender, 1992). A description of each scene and the percentage difference in area between the stimulus object and each of its distractor objects is presented in Appendix A. Figure 1 shows the picture trio (bananas) in which the distractors differed the most from the stimulus (about 40%). As may be seen in Appendix A, in seven of the stimuli the main object was slightly cropped by the picture's boundaries and in five the object was complete.

Area Measurement

All drawings were made within a 4 in. × 6 in. (approximately 10 cm × 15 cm) rectangle to ensure that the picture space had the same aspect ratio as the presentation slides (1:1.5). To measure the area of the main object in each slide, we projected the slide into a 4 in. × 6 in. (approximately 10 cm × 15 cm) rectangle and the outline of the main object was traced with black ink. To measure the main object's area in each of the subjects' drawings, we similarly darkened its outline with black ink. These outline drawings were digitized using the video camera and were then displayed on the

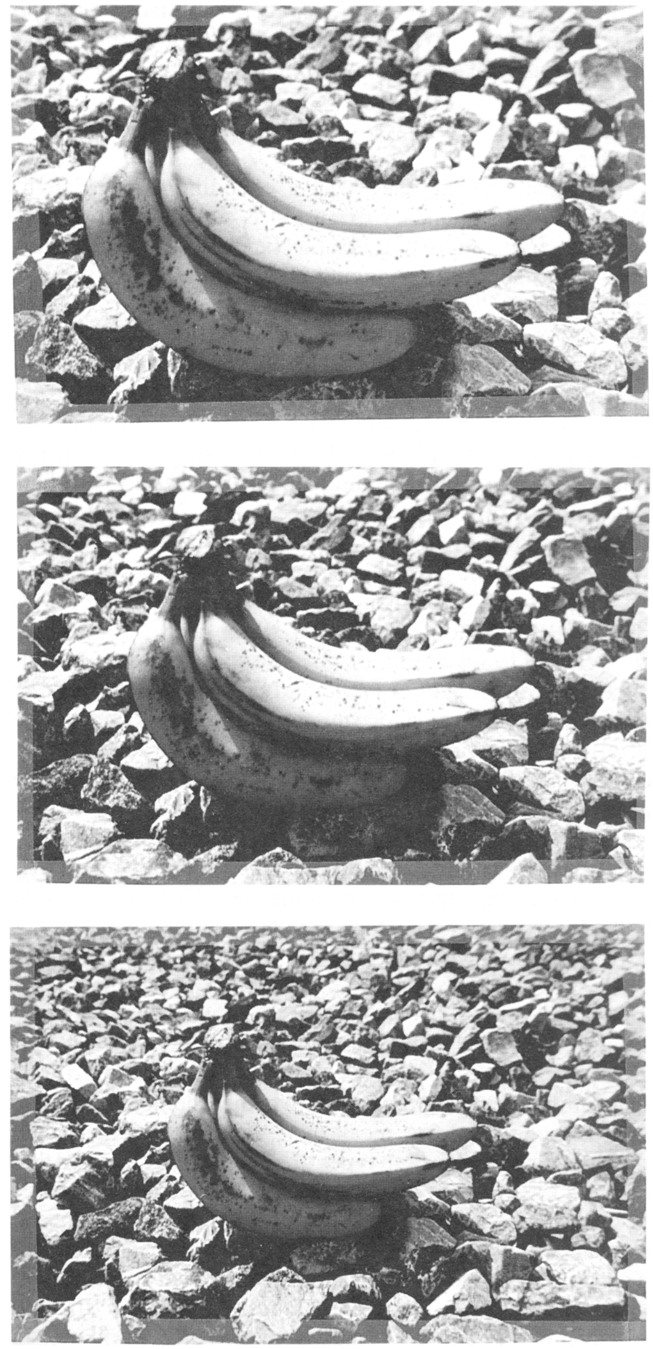

Figure 1. The close distractor, stimulus, and wide distractor version of bananas; the picture trio with the largest percentage difference between the stimulus object and each of its distractors (see Appendix A). (Black-and-white versions of the color stimuli are presented here.)

monitor. The experimenter delineated the outlined area to be calculated, and an area estimation program was run. The area was described in terms of both number of pixels and square tenths of inches (which corresponds to the grid sheets used in other experiments from this lab, in which area was manually estimated).

Design and Procedure

There were three conditions: control, test informed, and demo, with 27 subjects in each. In all three conditions, subjects were presented with the 12 target slides for 15 s each; slide presentation was followed by a drawing test and a recognition test. Subjects in all three conditions viewed the 12 stimuli in the same order. They were all requested to draw the same subset of 9 pictures in the drawing task and received the same counterbalancing conditions in the recognition test.

Counterbalancing of the test versions (target, close distractor, and wide distractor) in the recognition test was accomplished in the following manner. There were three test sets of slides. Each set contained one version of each of the twelve original slides in the same order as during presentation. Four pictures were targets (the same version as during presentation), four were close distractors, and four were wide distractors. No more than two of any classification was shown consecutively. Each scene was shown as a target in one test set, a close distractor in another set, and a wide distractor in the remaining set. Each of the three possible test sets were presented to one third of the subjects in each condition.

The only difference among the three conditions was the nature of the instruction subjects received prior to viewing the slides. Because of the importance of the instructions, these will be provided in detail. First, we describe the encoding instructions, and then we describe the instructions for the drawing task and recognition test, respectively.

Encoding instruction. The control condition was designed to replicate the boundary extension effect with the same type of instructions and tests as in previous research (Intraub et al., 1992; Intraub & Richardson, 1989). Subjects were told they would be shown 12 slides and were instructed to attend to the center of the screen. They were then given the following instruction (referred to as the "basic instruction" because it was read in all three conditions):

> Your task will be to remember each picture in as much detail as possible. The pictures will consist of a main object against a background. The background is just as important to remember as the main object.

After presentation, subjects took part in the drawing task, which was followed by the recognition test.

In the test-informed condition, in addition to the basic instruction subjects were informed of the format of the memory tests and were provided with a picture-viewing strategy. Test information was provided as follows:

> You will then be given two memory tests. For the first one, you will be asked to draw several of the pictures from memory as accurately as you can. For the second, you will be shown the same scenes again and will be asked to judge whether the views are the "same", "closer-up" or "farther away".

To explain what was meant, we then showed the subjects a series of four slides depicting closer and farther away views of a bicycle against a fence and told them to note that these photographs "are all of the same scene, but that when the camera is closer-up, you can see less of the scene than when it is farther away." (This procedure is part of the instruction for the recognition test in the other two conditions, as well as in all previous boundary recognition research.) We provided the subjects with the following strategy for viewing the pictures:

> Try to give both the object and the background equal attention and try to figure out their relation to one another. How much of the background does the object cover? Or, how large is the object in relation to the background? Keep in mind that you will be asked to draw some of the pictures later.

Subjects were then shown the 12 slides for 15 s each.

In the demo condition, subjects were given the basic instruction and were shown three slides (strawberries on a paper towel, spaghetti wrapped around the head of a fork, and dolphins being fed) for 15 s each. Following the presentation, we asked them to draw the spaghetti picture within a 4 in. × 6 in. (approximately 10 cm × 15 cm) rectangle on a response sheet, and we gave them the standard drawing instructions (described more fully in the *Drawing instructions* section). They were told to consider the edges of the rectangle to be the edges of the picture they saw and to draw the picture accordingly. The slide was then presented again so that subjects could see the distortion in their drawings. (All the drawings exhibited a large degree of extension.) We told subjects the following:

> I'd like you to compare what you just drew to the slide. How do your borders compare to the borders on the actual picture? If you're like most people, you probably drew much more of the scene than was represented in the photo.

The experimenter then discussed the drawings, pointing out that they had all included information that had not been present in the slide (e.g., the fork's handle). Subjects were told that what they had experienced is a common distortion that occurs in picture memory, and they were instructed to try to guard against it in the experiment. In addition to the basic instruction, these subjects received the following direction:

> Keep in mind the memory distortion you just saw in your drawings and try to prevent it. In other words, try to remember the pictures *exactly* as they appeared on the screen.

The 12 presentation slides were then shown for 15 s each.

Drawing instructions. The drawing task was begun immediately after the 12 pictures had been presented. To keep drawing time from exceeding 15–20 min, we asked all subjects to draw the same subset of 9 pictures (5 cropped and 4 not cropped). The drawing booklets contained a 4 in. × 6 in. (approximately 10 cm × 15 cm) rectangle for each picture along with its name. Subjects were instructed to draw the pictures in as much detail as possible and to keep the layout of the picture and relative size of the object as accurate as possible. They were told to consider the edges of the rectangle to be the edges of the picture they had seen on the screen and to draw the pictures accordingly. Subjects were told that they could alter the drawings when finished or use words to clarify them.

Recognition test instructions. In all three conditions, subjects were told that they would be shown the same 12 scenes as during presentation and that they would be required to judge whether each view was the same, closer, or farther away than the original version. We explained that when taking a picture of a scene, the camera can be moved closer to or farther away from the object, thereby showing more or less of the scene. We illustrated this by showing the same sample scene (bicycle against fence) that was shown to the test-informed subjects before presentation, to the control and demo condition groups at this point. The four views of the scene were presented, and subjects were told to note that all the pictures were of the same scene but that when the camera is closer less of the scene can be seen than when it is farther away.

In all three conditions, subjects were instructed to rate each scene in the test set as (−2) *much too close*, (−1) *slightly too close*, (0) *the same*, (1) *slightly too far*, or (2) *much too far* and to rate their confidence as (3) *sure*, (2) *pretty sure*, or (1) *not sure*. Subjects were also told that although all the scenes had been shown before, if they did not remember seeing a particular scene at all, they should circle DRP on their test forms, which meant, " don't remember picture."

Results

Drawings

Because there were only 9 pictures and they differed from one another in area, to avoid a possible bias, we eliminated from the drawing analysis the drawings of 7 subjects who did not draw all 9 pictures. This resulted in a total of 216 drawings in the control condition ($n = 24$), 216 in the test-informed condition ($n = 24$), and 234 in the demo condition ($n = 26$).

Using the procedure described in the Method section, we digitized each drawing and divided the area of the main object in the drawing by the area of the main object in the stimulus. This proportion, referred to as the "proportion drawn," was averaged across pictures and is shown for each condition in Table 1. In each case, the mean proportion drawn was significantly less than 1.00 ($p < .005$; see Table 1 for 95% confidence intervals). This shows that subjects in all three conditions reduced the size of the main object in the picture space and added more background. Neither a description of the tests nor a demonstration of the distortion itself prior to encoding, resulted in the elimination of boundary extension. Examples of drawings that yielded the mean proportion drawn for the light bulb in the control condition and in the demo condition are shown in Figure 2.

Because the two experimental conditions differed from each other in kind, planned comparisons between the control condition and each experimental condition were conducted using nonorthogonal contrasts in all of the following analyses. Planned comparisons showed that although subjects in all conditions had extended the pictures' boundaries, the degree of extension was reduced in both the test-informed condition, $F(1, 71) = 22.07$, $p < .001$, $MS_e = 70.93$, and the demo condition $F(1, 71) = 44.48$, $p < .001$, $MS_e = 142.98$, in comparison with the control group. This indicates that prior warning reduced but did not eliminate boundary extension.

The mean proportion drawn for each picture in each condition is listed in Appendix B. Inspection of these data indicates that the tendency to extend boundaries is not limited to a subset of the pictures. The proportion drawn was less than 1.00 for each individual picture in the control condition and in all but one or two pictures in the experimental conditions. A two-way 3 (instruction) × 9 (picture) analysis of

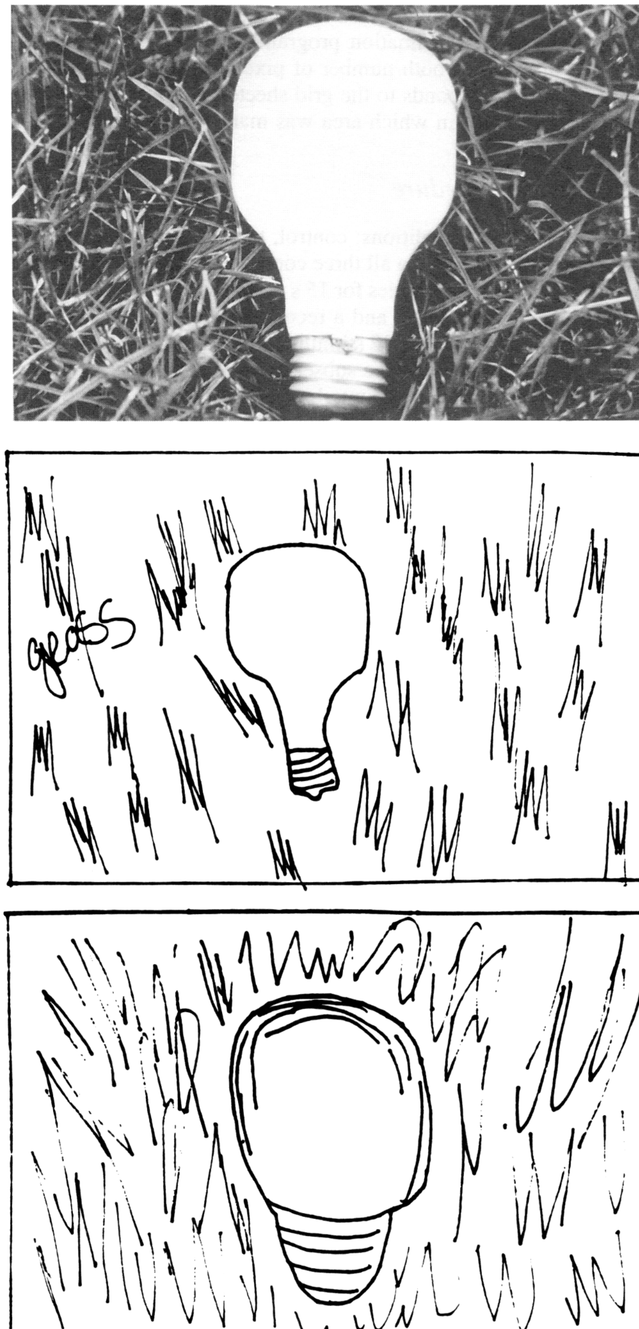

Figure 2. The light bulb stimulus (Panel a) and 2 subjects' drawings: a control condition drawing in which the drawn object covers .42 of the stimulus object area (Panel b) and a demo condition drawing in which it covers .82 of the stimulus object (Panel c). (Condition means for the light bulb were .46 and .83, respectively. Original pencil drawings were traced in black ink.)

Table 1
Mean Proportion of Main Object Drawn in Each Condition and the Upper (UL) and Lower (LL) Limits of the 95% Confidence Interval for Each

	Proportion drawn		Confidence interval	
Condition	*M*	*SD*	UL	LL
Control	.44	.14	.50	.38
Test informed	.68	.21	.77	.59
Demo	.78	.18	.85	.70

Note. Demo = demonstration.

variance (ANOVA) on the proportions showed that overall, pictures differed from one another in terms of the degree of extension, $F(8, 568) = 34.93$, $p < .001$, $MS_e = 235.73$. Planned comparisons, however, showed that the type of instruction did not interact with individual pictures when the control condition was contrasted with the test-informed condition, $F(8, 568) = 1.14$, $MS_e = 7.70$, nor when it was contrasted with the demo condition, $F(8, 568) = 1.09$, $MS_e = 7.35$. Overall, prior warning tended to reduce the degree of extension for all the pictures.

To determine whether pictures containing cropped objects were more greatly affected by the new instructions than those that did not contain cropped objects, we calculated the mean proportions for the five cropped pictures and for the four uncropped pictures. These means are shown in Table 2. A 2 (picture type) × 3 (instruction) ANOVA showed that overall, these two sets of pictures did not yield different degrees of extension, $F(1, 71) < 1$. More important, planned comparisons revealed that picture type did not interact with instruction when the control was contrasted with the test-informed condition, $F(1, 71) < 1$, or with the demo condition, $F(1, 71) = 1.29$, $p < .30$, $MS_e = 307.68$. Whatever encoding strategy the subjects used in the experimental conditions, it reduced the degree of boundary extension in comparison with that of the control group but did not differentially reduce it for pictures in which objects were cropped rather than those in which the objects were not cropped. Apparently, the concrete marker of boundary occlusion that characterizes cropped pictures was not useful in overcoming the distortion.

Recognition

Mean confidence ratings were virtually identical across the three conditions (2.2–2.3). Given the 3-point scale of *sure* (3), *pretty sure* (2), or *not sure* (1), subjects reported being pretty sure or sure 90% of the time. They selected the "don't remember picture" option in only 1.3% of the trials.

Subjects' mean ratings of whether test pictures were (−2) *much too close*, (−1) slightly too close, (0) *the same*, (1) *slightly too far*, or (2) *much too far* are referred to as *boundary scores*. These could range from (−2) much closer to (2) *much farther*, with a rating of 0 indicating *same*. Table 3 shows the mean boundary score for each condition when the test picture was the same as the stimulus (target). The negative scores show that when faced with the same picture again, subjects tended to rate it as being a closer view than before, thus indicating that their memory for the stimulus included extended boundaries. These negative boundary scores differed significantly from (0) *same* in all three conditions ($p < .025$; see Table 3 for 95% confidence intervals). The mean boundary score for each picture is shown in Appendix C. Inspection of these data indicates that extension occurred for most of the pictures in each condition. As was the case with the drawings, neither type of instruction eliminated boundary extension. Planned comparisons contrasting the control condition with each experimental condition revealed that the overall degree of the distortion was reduced in the test-informed condition, $F(1, 78) = 4.64$, $p < .03$, $MS_e = .78$, but not in the demo condition, $F(1, 78) = 3.03$, $p < .09$, $MS_e = .51$.

A similar pattern of results was obtained in an analysis of hits (cases in which subjects correctly identified targets as *same*). Subjects' hit rate was 51% in the control condition, 68% in the test-informed condition, and 56% in the demo condition. Planned comparisons on the number of hits revealed the same pattern of results as analysis of the boundary scores: The hit rate increased significantly in the test-informed condition, $F(1, 78) = 4.11$, $p < .05$, $MS_e = 6.00$, but not in the demo condition, $F(1, 78) < 1$.

The mean boundary scores for close and wide distractors in each condition are shown in Table 4. A 2 (distractor type) × 3 (instruction) ANOVA showed that subjects successfully discriminated between close and wide distractors, $F(1, 78) = 233.79$, $p < .001$, $MS_e = 46.09$. Planned comparisons showed that responses to the distractors became less negative in the experimental conditions as compared with the control group—test-informed condition, $F(1, 78) = 8.12$, $p < .006$,

Table 2
Mean Proportion of the Main Object Drawn for Cropped Objects and Whole Objects in Each Condition

	Cropped objects		Whole objects	
Condition	*M*	*SD*	*M*	*SD*
Control	.43	.12	.45	.20
Test informed	.67	.20	.70	.26
Demo	.80	.12	.75	.31

Note. Demo = demonstration.

Table 3
Mean Boundary Score and the Upper (UL) and Lower (LL) Limits of the 95% Confidence Interval for Each Condition

	Boundary score		Confidence interval	
Condition	*M*	*SD*	UL	LL
Control	−.45	.37	−.31	−.60
Test informed	−.21	.41	−.07	−.38
Demo	−.26	.44	−.08	−.43

Note. Demo = demonstration.

Table 4
Mean Boundary Scores for Close and Wide Distractors in Each Condition

	Distractor type	
Condition	Close	Wide
Control		
M	−.90	.04
SD	.42	.46
Test informed		
M	−.79	.50
SD	.39	.47
Demo		
M	−.61	.37
SD	.67	.41

Note. Demo = demonstration.

$MS_e = 2.13$, and demo condition, $F(1, 78) = 9.80, p < .002$, $MS_e = 2.57$—indicating a reduction of boundary extension in memory. Inspection of the data in Table 4 suggests that this was due to the greater tendency of the subjects in the control condition to accept wide distractors as targets or even to rate them as closer than before as well as to their tendency to rate the close distractors as being even closer. The interaction of distractor type and condition was significant when the control condition was contrasted with the test-informed condition, $F(1, 78) = 4.24, p < .04, MS_e = .84$, but not for the demo condition, $F(1, 78) < 1$. Apparently, prior warning about the recognition test in the test-informed condition enhanced subjects' ability to detect wide distractors.

The most important question regarding the distractors was whether the results would replicate the response asymmetry found in previous research. If the subjects' pictorial representations contained extended boundaries, then their reactions to close and wide distractors should differ; wide distractors should be perceived as looking more like the stimulus than close distractors. We tested for this asymmetry in two ways. In the first, we analyzed the number of false alarms to each distractor type (i.e., trials in which subjects mistook the distractor for a target). The percentage of false alarms to close and wide distractors is shown in Table 5. Consistent with previous research, subjects made more false alarms to wide distractors than to close distractors, $F(1, 78) = 16.16, p < .001, MS_e = 18.67$. This was the case in all three conditions. Planned comparisons showed that this asymmetry was maintained in both experimental conditions. Distractor type did not interact with instruction when the control condition was compared with the test-informed condition, $F(1, 78) = 1.35, p < .20, MS_e = 1.56$, or with the demo condition, $F(1, 78) < 1$.

The second way we addressed the asymmetry issue was to analyze the boundary scores for the close and wide distractors. To provide a very conservative test of the asymmetry, we selected only those subjects whose mean boundary scores were negative for close distractors and positive for wide distractors (see Table 6). We wanted to determine whether subjects who tended to correctly identify the distractor types, would recognize that they differed equally from the stimulus. Absolute values of the scores were compared in a 2 (distractor type) × 3 (instruction) analysis to determine whether they differed in magnitude. As in previous research, wide distractors were rated as closer to same than were close distractors, $F(1, 48) = 11.70, p < .001, MS_e = 1.78$. Planned comparisons showed that this asymmetry was maintained across all three conditions; there was no interaction of distractor type and instruction in either comparison, $F(1, 48) < 1$, in both cases.

Table 5
Percentages of False Alarms to Close and Wide Distractors in Each Condition

Condition	Distractor type	
	Close	Wide
Control	28%	52%
Test informed	34%	46%
Demo	27%	42%

Note. Demo = demonstration.

Table 6
Mean Boundary Scores for Those Subjects Whose Mean Scores Were Negative for Close Distractors and Positive for Wide Distractors in Each Condition

Condition	Distractor type	
	Close	Wide
Control (n = 13)		
M	.87	.40
SD	.39	.19
Test informed (n = 21)		
M	.83	.64
SD	.39	.43
Demo (n = 17)		
M	.73	.57
SD	.34	.35

Note. Demo = demonstration.

Unlike the drawing task, the present recognition test did not allow for a statistical analysis of differences between pictures with cropped main objects and those without. First, only four pictures served as targets in each test set, and second, because of the counterbalancing procedure, these four pictures were not equally divided between cropped and uncropped pictures in each set. In two sets, targets included three cropped and one uncropped picture and in the remaining set, this was reversed. The mean ratings for the three uncropped pictures in one recognition test set in each condition (n = 9) and the mean ratings for the six cropped pictures in the other two sets (n = 9 for each picture) suggest that instruction may have differentially affected memory for cropped and uncropped pictures in recognition in a manner consistent with the concrete marker hypothesis. For cropped and uncropped pictures in the control condition the boundary scores were −.48 and −.63, respectively, in the test-informed condition; mean scores for these same pictures were −.41 and −.19, and in the demo condition they were −.33 and −.26, respectively. Because of the small number of pictures (and subjects), this apparent interaction (which appears to be most pronounced when the control condition is compared with the test-informed condition) must be considered cautiously, but it may well be worth pursuing in future research.

Discussion

Subjects tended to remember having seen more of a scene than was actually shown in a photograph. This occurred regardless of the specificity of their test expectations. Neither specific information about the tests nor experience with the phenomenon in advance eliminated the subjects' tendency to extend the picture's boundaries. Boundary extension is clearly a strong and highly replicable phenomenon that cannot be attributed to a mismatch between the subjects' expectations about what will be tested and the unexpected focus of the boundary memory tests. Although subjects in the demo and test-informed conditions understood the importance of remembering exactly what information filled the pictures' boundaries, they were unable to prevent the distortion.

Perhaps the most compelling outcome was that obtained in the demo condition. In this condition, subjects actually experienced boundary extension at the beginning of the session and were instructed to guard against it as they encoded a new set of pictures. It is important to point out that subjects' reactions to the demonstration were similar to those typically observed during demonstrations of optical illusions. There was surprise, interest, and a desire to override the phenomenon. Yet moments later when they did the same task again with new pictures, the same phenomenon occurred.

Subjects in both the demo and test-informed conditions reduced the size of the main object in their drawings and included more of the background within the picture space. In both cases, prior warning did not result in the elimination of this unidirectional bias, but it served to attenuate it, in comparison with the control condition. This shows that although boundary extension persisted, the subjects had indeed tried to follow our instructions and to remember the spatial content of the pictures.

Recognition responses also showed that subjects in all three conditions remembered the photographs as having included more of the scene than had actually been the case. They rated target pictures as depicting closer views than the stimulus picture, and showed a striking asymmetry in their responses to the distractors. They rated the wide distractors as being more similar to the stimulus than the close distractors, even though the distractor types differed by the same amount from the stimulus picture (in terms of the area of the main object in the picture space). They were also more likely to falsely accept wide distractors as targets than close distractors.

As was the case in the drawing task, prior warning tended to lead to a reduction in the degree of extension for targets as compared with the control condition. This apparent reduction was significant for the test-informed subjects (who had prior knowledge about the recognition test procedure) but did not reach significance for those in the demo condition. As compared with subjects in the control condition, however, in both prior warning conditions, subjects' overall response to the distractors was less negative, suggesting a reduction in the degree of extension.

The reason for the reduction in boundary extension seen in the two prior warning conditions should be considered carefully. One important question is whether those subjects' pictorial representations were actually more accurate than the control subjects' representations or whether the reduction in extension was the result of response bias. Because subjects in the demo condition were educated about the unidirectionality of the phenomenon, they may have tried to override it by skewing their responses in the opposite direction (e.g., by deliberately pulling the boundaries in when they drew). Indeed, inspection of the drawing results shows that the drawings made by subjects in the demo condition had the smallest degree of boundary extension among the three groups. Response bias may have played a role in the reduction of boundary extension in this condition.

The response bias hypothesis, however, cannot account in any way for the significant reduction of boundary extension in the test-informed condition as compared with the control condition. For these subjects, the instructions contained no directional information: They were simply told what would be tested and how it would be tested. Nothing in their instructions suggested that they should bias the boundaries either inward or outward. The reduction in degree of extension in this condition indicates that subjects had indeed attempted to attend to the picture layout more than subjects in the control condition and that these attempts resulted in more veridical representations.

Analysis of subjects' drawings showed that prior warning reduced boundary extension by the same amount regardless of whether the stimulus had contained a cropped object or not. This suggests that the encoding strategy used to improve accuracy did not depend on implicit verbalization of the concrete markers provided by object occlusion (e.g., "the front and rear edges of the car were cropped"). Instead, subjects in the prior warning conditions may have consciously directed their attention to the boundaries and to the spatial layout of the picture.

The fact that boundary extension was obtained in all three encoding conditions (including one in which response bias alone might have been expected to eliminate it) shows that it is a very robust phenomenon that cannot be attributed to relatively superficial encoding strategies. The results are consistent with the perceptual schema hypothesis, which attributes boundary extension to the activation of an abstract representation of the likely structure of a scene just outside the picture's boundaries—a representation that is so integral to the subject's understanding of the picture that it becomes incorporated in the pictorial representation. It is important to note that *likely structure* does not require that the scenes be *typical.* Boundary extension occurred both for pictures with highly probable backgrounds (e.g., basketball on gym floor; see Appendix A for a description of the scenes) as well as for those with relatively unlikely backgrounds (e.g., bananas on rocks and light bulb on grass, which are shown in Figures 1 and 2, respectively). As described earlier, the perceptual schema apparently includes information that would be likely to be seen were the subject able to make a fixation outside a given picture's boundaries.

One of the attractive aspects of this theoretical perspective is that the proposed perceptual schema is not viewed as a representation that is specific to picture perception. We presume that pictures are perceived using the same visual–cognitive system that underlies all visual perception and that the perceptual schema is a fundamental component of that system. According to the theory, the perceptual schema is a mental structure that underlies the comprehension of individual views of a scene, whether that view comes from a single eye fixation during scanning, from a single shot in a series of viewpoint shifts in a movie or video display, or from a single static photograph.

So far, research on boundary extension has lent support to the perceptual schema hypothesis. However, it is important to point out that regardless of whether this particular theory stands up to future tests, the phenomenon of boundary extension itself is deserving of further study. It is a persistent characteristic of picture memory under many types of conditions, and as such, it must be explained if we are to understand the nature of pictorial representation.

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Appendix A

Percentage Difference in Area Between the Stimulus Object and Each of the Distractor Objects (Close and Wide)

Picture	Close distractor	Wide distractor
Basketball on gym floor	38.03	41.39
Backpack[a] on leafy ground	11.00	16.02
Typewriter on desk top	11.29	14.21
Cards[a] on table top	11.91	9.18
Toilet paper roll on tile	29.91	34.49
Bowl of Cheerios[a] cereal on table	8.79	11.91
Tape dispenser on floor	45.90	38.52
Car[a] in parking lot with trees	35.08	33.01
Light bulb[a] on lawn	29.80	35.10
Book[a] on outdoor wood chips	19.98	18.09
Bananas on rocks	41.21	43.75
Tire[a] leaning on cement wall	14.27	12.98
Mean difference	24.76	25.72

[a] The main object in these pictures was slightly cropped by 1–2 of the picture's edges.

Appendix B

Mean Proportion of Main Objects Drawn for Each Picture in Each Condition

	Condition		
Picture	Control	Test informed	Demo
Basketball	.64	1.02	1.00
Typewriter	.52	.78	.88
Car	.68	.95	1.10
Toilet paper roll	.40	.49	.60
Light bulb	.46	.76	.84
Bowl of Cheerios cereal	.26	.47	.59
Cards	.35	.54	.66
Bananas	.30	.53	.57
Tire	.34	.60	.78

Appendix C

Boundary Scores for Each Picture in Each Condition

	Condition		
Picture	Control	Test informed	Demo
Basketball	−.11	−.11	−.22
Typewriter	−.56	.00	.00
Car	−.33	−.22	−.11
Toilet paper roll	−.22	−.11	.11
Backpack	−.44	−.11	.00
Light bulb	−.33	−.44	−.33
Book	−.25	−.11	−.44
Bowl of Cheerios cereal	−.67	.00	−.67
Tape	.11	.00	.14
Cards	−.56	−.22	.00
Bananas	−.75	−.67	−.78
Tire	−1.22	−.56	−.78

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