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Effects of Perceiving and Imagining Scenes on Memory for Pictures

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Boundary extension is the tendency to remember having seen a greater expanse of a scene than was shown. Four experiments tested whether a picture must depict a partial view of a scene for the distortion to occur. The premise was that partial views activate a *perceptual schema*, a representation of the expected scene structure outside the view. Participants were 473 undergraduates. Experiments 1 and 2 tested recognition memory and recall of 16 outline-objects presented in outline-scenes versus presentation on blank backgrounds. Experiments 3 and 4 compared memory for outline-objects when scene context was or was not imagined. Boundary errors consistent with the perceptual schema hypothesis only occurred for partial views (perceived or imagined). Results suggest that scene perception and imagination activate the same schematic representation.

When viewers remember a photograph of a scene, they tend to remember having seen a greater expanse of the scene than was actually captured in the photograph, a phenomenon referred to as *boundary extension* (Intraub & Richardson, 1989). Intraub and her colleagues (Intraub, 1992; Intraub, Bender, & Mangels, 1992) proposed that comprehension of photographs and, in fact, comprehension of any partial view of the visual world may involve the activation of a *perceptual schema*. This is a schematic mental representation of the information that is likely to exist just outside the perimeter of the current view. These expectations are so fundamental to comprehension of the view that the observer tends to remember having seen this expected information.

This theoretical perspective has implications not only for models of spatial memory but for other issues in the field of visual cognition. One of these is the classic controversy about how we perceive a stable, continuous visual world when the input to our visual system is composed of numerous discrete eye fixations. In recent years, many researchers have rejected the notion that information from each fixation is held in a sensory memory where it is integrated with preceding and following fixations (e.g., Hochberg, 1978, 1986; Irwin, Brown, & Sun, 1988; McConkie & Currie, 1996; O'Regan, 1992; Rayner & Pollatsek, 1992). Hochberg and others (Hochberg, 1978, 1986; Irwin et al., 1988) have proposed that detailed visual information from individual eye fixations is not maintained following the execution of the fixation but that an abstract *mental schema* may serve to guide perception of successive views and provide a general context for comprehension and memory.

We are interested in the possibility that the perceptual schema proposed to explain boundary extension may be the same representation as this mental schema. The notion is that regardless of whether a partial view is delivered by a picture or by an eye fixation, the same mental representation may be activated as part of the perceptual process. A fundamental step in testing the viability of this hypothesis is to determine if boundary extension is limited to stimuli that depict a partial view. If it occurs for all types of visual displays, regardless of what is depicted, then the notion of a *partial view* may prove to be so vague as to have little value as a theoretical construct.

The perceptual schema hypothesis also has implications for the question of whether visual perception and visual imagery share common mental structures. Research on the similarity of responses to perceived versus imagined stimuli (e.g., Finke, 1980, 1985; Shepard, 1984), the interaction of perception and imagination (e.g., Farah, 1989; McDermott & Roediger, 1994), and the neuropsychological underpinnings of these processes (Farah, 1988) have provided interesting evidence in support of shared mental structures, although there are certainly different perspectives on this issue (e.g., Intons-Peterson, 1996; Pylyshyn, 1981; Reisberg, 1996). The perceptual schema hypothesis allows us to take another approach to exploring the relationship between perception and imagination. If the perceptual schema contains expectations about the spatial layout of scenes, it is possible that it can be activated not only through a stimulus-driven route (i.e., presentation of a partial view) but through a top-down route (i.e., imagination of that same view). In the paradigm we describe here, the effects of imagining and perceiving scenes on boundary memory are examined in a manner that eliminates some of the problems related to

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experimenter bias and the use of tacit knowledge that has yielded controversy in the interpretation of many behavioral experiments that compared imagination and perception (Farah, 1988; Intons-Peterson, 1983).

In the two background sections that follow, we first review some of the empirical hallmarks of boundary extension to establish the types of patterns that are obtained following presentation of close-up and wide-angle views of the same scene. We then provide a more detailed description of the perceptual schema hypothesis and the more general extension–normalization model that has provided the framework for our research.

Boundary Extension

Evidence for boundary extension has been obtained in a number of different types of memory tests. When participants were asked to draw photographs of scenes from memory, their drawings tended to contain a greater proportion of the background than actually was shown, and the scale of all objects and background elements decreased accordingly (Intraub, 1992; Intraub & Bodamer, 1993; Intraub & Richardson, 1989; Legault & Standing, 1992). The drawings can be described as depicting more wide-angle views than had the stimuli. In several experiments, the distortion was so great that objects that had filled the majority of the picture space were drawn as having covered only about one third of their original area (Intraub, 1992; Intraub & Berkowits, 1996; Intraub, Gottesman, Willey, & Zuk, 1996). The ability to recall picture boundaries was also tested by requiring participants to physically move boundaries on a test picture to indicate their remembered location, and as in the drawings, boundary extension occurred (Nyström, 1993).

Evidence for boundary extension has also been obtained in a variety of recognition tests (Intraub, 1992; Intraub et al., 1992; Intraub & Bodamer, 1993; Intraub & Richardson, 1989). Participants in these experiments received a recognition test following presentation. When presented with a target picture (i.e., the same picture as during presentation), they tended to rate it as *closer-up* than before, thus indicating that they remembered it as having shown more of the scene. In recognition tests that used distractors that showed slightly less of the scene (close-up distractors) or slightly more of the scene (wide-angle distractors), an asymmetrical response pattern was obtained (Intraub et al., 1992; Intraub & Bodamer, 1993; Intraub & Richardson, 1989). Viewers were much more likely to mistake a wide-angle distractor, rather than a close-up distractor, as being the same as the presentation picture. They also rated the wide-angle distractors, as looking more like the original view than did the close-up distractors. This important asymmetry provides additional evidence that the participant's mental representation contained extended boundaries.

The phenomenon also appears to be quite robust. Boundary extension occurs following picture durations as long as 15 s (e.g., Intraub & Richardson, 1989), and as brief as 250 ms (Intraub et al., 1996). Across studies, memory was tested for sets ranging in size from 3 to 20 pictures, and boundary extension was obtained in all cases (see Intraub et al., 1996). Although, initially, boundary memory was tested after retention intervals of minutes or days, in recent research, boundary extension was obtained following retention intervals as brief as 1 s following successive presentation of photographs for one third of a second each with no interstimulus interval (Intraub et al., 1996)—a rate of presentation that mimics the average fixation frequency of the eye (Yarbus, 1967). The significance of this finding is that it lends support to the speculation that the perceptual schema can be activated rapidly enough to play a role in the integration of eye fixations.

In other research, in an attempt to foster a more painstaking perusal of the picture's details and thus minimize or eliminate boundary extension, photographs of scenes were inverted during presentation. This had little if any effect on the degree of the distortion (Intraub & Berkowits, 1996). Boundary extension also occurred regardless of whether a boundary cropped an object or not (Intraub & Bodamer, 1993; Intraub & Richardson, 1989), thus ruling out the Gestalt principle of object completion as an explanation (see Ellis, 1955).

Intraub and Bodamer (1993) tried to eliminate the distortion through instruction. In one condition, before viewing the study set, participants were provided detailed information about the boundary test they would receive, thus calling their attention to the boundaries. In another condition, participants were given a demonstration of boundary extension prior to the experiment. These participants experienced the phenomenon during the demonstration and were then challenged to prevent it from occurring during the experiment. In both conditions, prior warning served to attenuate the distortion (as compared with a control group) but did not eliminate it.

Boundary extension occurs for picture views that observers consider to be close-ups, prototypic views, and wide-angle views. For example, Intraub et al. (1992) reported that if tested within minutes of presentation, boundary extension was greatest for close-ups and decreased as picture view widened, with wide-angle views sometimes yielding a small degree of extension or no directional distortion. This pattern has been replicated by using various recognition test procedures (Intraub et al., 1992, 1996) and a recall task in which participants drew the pictures from memory (Intraub & Berkowits, 1996; Intraub et al., 1996). A possible explanation of why memory for photographs of scenes should yield this pattern of errors is offered in the following model.

Extension–Normalization Model

As a preliminary attempt to explain boundary extension, Intraub and her colleagues (Intraub, 1992; Intraub et al., 1992, 1996) proposed an extension–normalization model of picture memory. The model is characterized by two types of schematic structures, each of which influences the mental representation of a remembered scene in a different way. The first component, referred to as the *perceptual schema,* is a mental map of the likely structure of the real-world scene that a photograph only partially reveals. It represents general expectations about what one would see if one could make an eye fixation just outside the picture's boundaries.

The perceptual schema is not a detailed sensory record, nor is it a list of probable items. As discussed previously, it may be similar to, or perhaps the same as, the mental schema proposed by Hochberg (1978, 1986) to account for the integration of successive views during visual scanning. The perceptual schema is conceptualized as an abstract representation of the expected layout of the continuous scene from which the partial view (shown in the picture) was taken.

The assumption is that to fully understand a partial view, particularly a close-up, it is necessary to take into account the scene context from which it was culled. Consider the following example, offered by Intraub and Richardson (1989). A photographic portrait of a friend actually shows a disembodied head. Yet, one does not gasp in horror when it is shown. Comprehension of that close-up seems to include an analysis of physical features along with an understanding that the friend and the surrounding background "continue" beyond the edges of the picture. Without the latter, the initial reaction to close-ups such as these would be one of shock, or at least surprise. Yet a portrait seems to be readily interpreted as a close-up view of a continuous scene.

When the viewer remembers the portrait, he or she retrieves not only what was physically presented but what was understood about the larger scene context. As a result, the highly probable part of the schema that encompasses expected information just outside the picture's boundaries is remembered as having actually been seen. This allows for a possible explanation for the decrease in boundary extension as more wide-angle views are presented. If the most salient area of a picture is the main object and the area immediately surrounding it, in a wide-angle picture a lot of the expected surrounding area is actually shown in the picture. For close-ups, however, much of the surrounding area is not physically present, although it is understood to exist through activation of the perceptual schema. A close-up imparts a greater sense of expectancy, requires a greater reliance on the schema, and thus yields a more pronounced distortion.

The second component of the extension–normalization model is normalization. Intraub et al. (1992) proposed that a second, distinct component influences memory for the scale of a picture because, over time, they had observed some unexpected changes in memory for the picture views. First of all, boundary extension was greater when tested immediately following presentation than when tested after a 2-day delay. However, perhaps more important, the pattern of errors changed over time, with the more close-up items in the set yielding boundary extension and the more wide-angle pictures yielding boundary restriction. Although activation of the perceptual schema leads immediately to boundary extension in memory, as time passes, it appears that the representations begin to normalize toward the average view depicted in the stimulus set.

The tendency for items to normalize in memory is a long-recognized phenomenon (e.g., Bartlett, 1932; Gibson, 1969). In fact, participants will remember having seen the average stimulus in a set even when it was never actually presented (Franks & Bransford, 1971). Normalization would lead to restriction of relatively wide-angle views and extension of relatively close-up views. Thus, although initially all of the pictures would tend to be remembered with extended boundaries (due to the activation of the perceptual schema when the pictures were first perceived), over time, normalization would counteract this unidirectional bias. Indeed, the degree of boundary restriction experienced for the same wide-angle pictures depended on the heterogeneity of the picture set (Intraub et al., 1992).

In that research, a 5-point boundary recognition scale ranging from -2 (*picture view much too close-up*) to 0 (*picture view the same*) to $+2$ (*picture view much too far*) was used 2 days following presentation. When only wide-angle pictures were presented to the participants (low heterogeneity), a small degree of restriction was obtained; the mean boundary rating was $+.07$. When the same wide-angle pictures were mixed with prototypic pictures, thus creating a more heterogeneous picture set, the mean boundary rating was $+.32$.

According to the extension–normalization model, the perceptual schema involves expectations about the continuation of a scene beyond what can currently be viewed. It is activated by the presentation of a partial view. Normalization, on the other hand, requires only that we have heterogeneity in the picture set. It will occur regardless of whether or not a picture depicts a partial view. If our model is correct, then boundary extension should not be obtained for all types of pictures, although normalization, as a more general phenomenon, may. Boundary extension should only occur for pictures that evoke the perceptual schema. These predictions were tested in Experiments 1 and 2.

If a partial view is necessary for activating the perceptual schema, another question is whether the partial view must be physically presented or whether imagination of a view would have the same effect. This question was addressed in Experiments 3 and 4.

The four experiments that follow test the perceptual schema hypothesis by examining spatial memory for pictures of objects when the objects are part of a scene (with scene context either provided visually or imagined by the observer) and when the objects are not in a scene (i.e., objects on blank background). According to our developing model, different patterns of boundary errors should be obtained under these two conditions. Positive results would provide important groundwork for the viability of the perceptual schema hypothesis. They would also support the view that a common representation underlies both perception and imagination of scenes and that its activation has important consequences for memory.

Experiment 1

According to the extension–normalization model, pictures that do not depict a partial view should not activate the perceptual schema and therefore should not yield boundary extension in memory. However, an alternative view is that rather than reflecting activation of a scene schema, boundary extension may reflect a more general process. For example, perhaps items tend to become smaller in memory, or perhaps information tends to be remembered as being farther from an edge than it actually was due to a relatively low-level, nonschematic cause.

Memory psychophysics research has provided evidence that area estimations of forms are distorted in a predictable manner during perception and that this distortion becomes even more pronounced in memory (e.g., Kemp, 1988; Kerst & Howard, 1978; Moyer, Bradley, Sorenson, Whiting, & Mansfield, 1978). These experiments were not designed to test memory for boundaries, and there is controversy as to whether they reflect distortions in the mental representation or response bias in the area estimation task. Still, the finding of a systematic distortion of size for simple forms raises the possibility that boundary extension may reflect a more general process than that offered by the perceptual schema hypothesis.

If this alternative hypothesis is correct, then we should obtain the same pattern of boundary errors for pictures of objects, regardless of whether the objects are presented within a partial view or not. This would serve to disprove the perceptual schema hypothesis or, at best, make it so vague (i.e., everything is a scene) as to require a new formulation.

In a short report, Legault and Standing (1992) provided tentative support for the perceptual schema hypothesis by showing that boundary extension occurs for photographs of scenes but not for outline drawings of main objects traced from each scene onto a blank background. Although suggestive, because the number of correct responses was not reported, it is unclear whether their finding of no directional distortion for the objects (without a scene context) was due to the lack of a partial view or to a ceiling effect in memory for the objects. Moreover, because their comparison of scenes and nonscenes were confounded with the medium of presentation (photographs vs. line drawings), it is unclear which was the determining factor. It is important to determine if outline drawings of scenes would yield the same unidirectional distortion of the boundaries as do the richly detailed, color photographs that had, to this point, been used to test memory for pictorial expanse.

In Experiment 1, participants were presented with photographs of objects within natural scene contexts (*photograph-scenes*), outline drawings in which the main object and background were traced (*outline-scenes*), or outline drawings in which the main object alone was traced on a blank background (*outline-objects*). Boundary memory for both close-up and wide-angle versions of these types of pictures was tested, using a recognition test procedure, to determine the following: (a) whether medium of presentation would affect memory for the expanse of a picture (photograph-scenes vs. outline-scenes), and (b) whether the presence of a scene context would affect memory for the expanse of a picture, as predicted by the extension–normalization model (outline-scenes vs. outline-objects).

Method

Participants. Participants were 141 University of Delaware undergraduates (69 women and 72 men) who elected to take part in the departmental subject pool for a general psychology course.

Stimuli. There were three types of stimuli: photograph-scenes, outline-scenes, and outline-objects. The photograph-scenes were photographs of 16 scenes in which a single object was presented on a simple natural background (e.g., office chair in front of a stone wall; see Appendix A for stimulus descriptions). There was a close-up view and a wide-angle view of each scene, yielding 32 photograph-scenes. The outline-scenes were created by tracing the main object and the background from each of the 32 photographs. The outline-objects were created by tracing only the main object in each photograph, leaving the background blank. Therefore, in each stimulus type, the main object was the same size and in the same location in the picture space. Figure 1 shows one of the 16 scenes (the "office chair") as a function of stimulus type and view.

Apparatus. The slides were projected on a rear-projection screen by using one channel of a three-channel projection tachistoscope, with UniBlitz shutters (Model 225-L) and shutter drives (Model SD-122B) controlled by an Apple II Plus computer. Participants sat in three rows with 3–4 seats in each, centered in front of the screen in a dimly lit room. The distance between the screen and the front, center, and back rows was 74, 118, and 157 inches (1.88, 3.00, and 3.99 m), respectively. The image size was 22¾ in. × 15 in. (57 cm × 38 cm). The approximate visual angles for participants sitting in the center of the front and back rows were 17° × 12° and 8° × 5°, respectively. Informal inspection in previous research suggested no difference in boundary memory for participants sitting in different rows.

Design and procedure. Participants took part in one of three conditions: photograph-scene ($N = 47$), outline-scene ($N = 49$), or outline-object ($N = 45$). In each condition, participants viewed 16 pictures for 15 s each. Half of the pictures were close-up views, and half were wide-angle views. View was counterbalanced across participants such that each specific scene (or outline-object) appeared as a close-up or wide-angle view equally often. Picture views were intermixed such that no more than three consecutive pictures were close-ups or wide-angle views. Participants were told to remember the size and location of everything in the picture space.

Immediately after presentation, the recognition test instructions were read. Then, the pictures were presented again, in the same order, except that half were shown in the same view as before (target pictures), and half were shown in the opposite view (distractor pictures). This yielded four test conditions: close-ups tested by close-ups (CC), wide-angle views tested by wide-angle views (WW), close-ups tested by wide-angle views (CW), and wide-angle views tested by close-ups (WC). Targets and distractors were randomized with the constraint that no two consecutive pictures were in the same test condition. Each picture was presented for 20 s while participants rated it on a 5-point boundary scale as 0 (*same*), −1 (*slightly closer-up, object slightly bigger*), −2 (*much closer-up, object much bigger*), +1 (*slightly more wide-angle, object slightly smaller*), or +2 (*much more wide-angle, object much smaller*). Participants provided a confidence rating of *sure, pretty sure,* or *not sure* for each response. A *don't remember picture* option was provided in case participants did not remember a picture at all.

The 5-point boundary scale was similar to the one used in previous boundary extension research (Intraub et al., 1992; Intraub & Richardson, 1989), differing only in its reference to object size (e.g., *object much bigger*), to clarify what is meant by *more close-up,* and so forth, for all three stimulus types. More important, as part of the instructions that were provided just before the recognition test, the scale was explained using a demonstration. In the demonstration, participants were presented with four views of a sample photograph-scene, outline-scene, or outline-object (depending on the condition) to illustrate how that scene (or outline-object) would look if a more close-up or a more wide-angle view of the scene were presented. The sample scene was the same scene that was used in this demonstration in previous research.

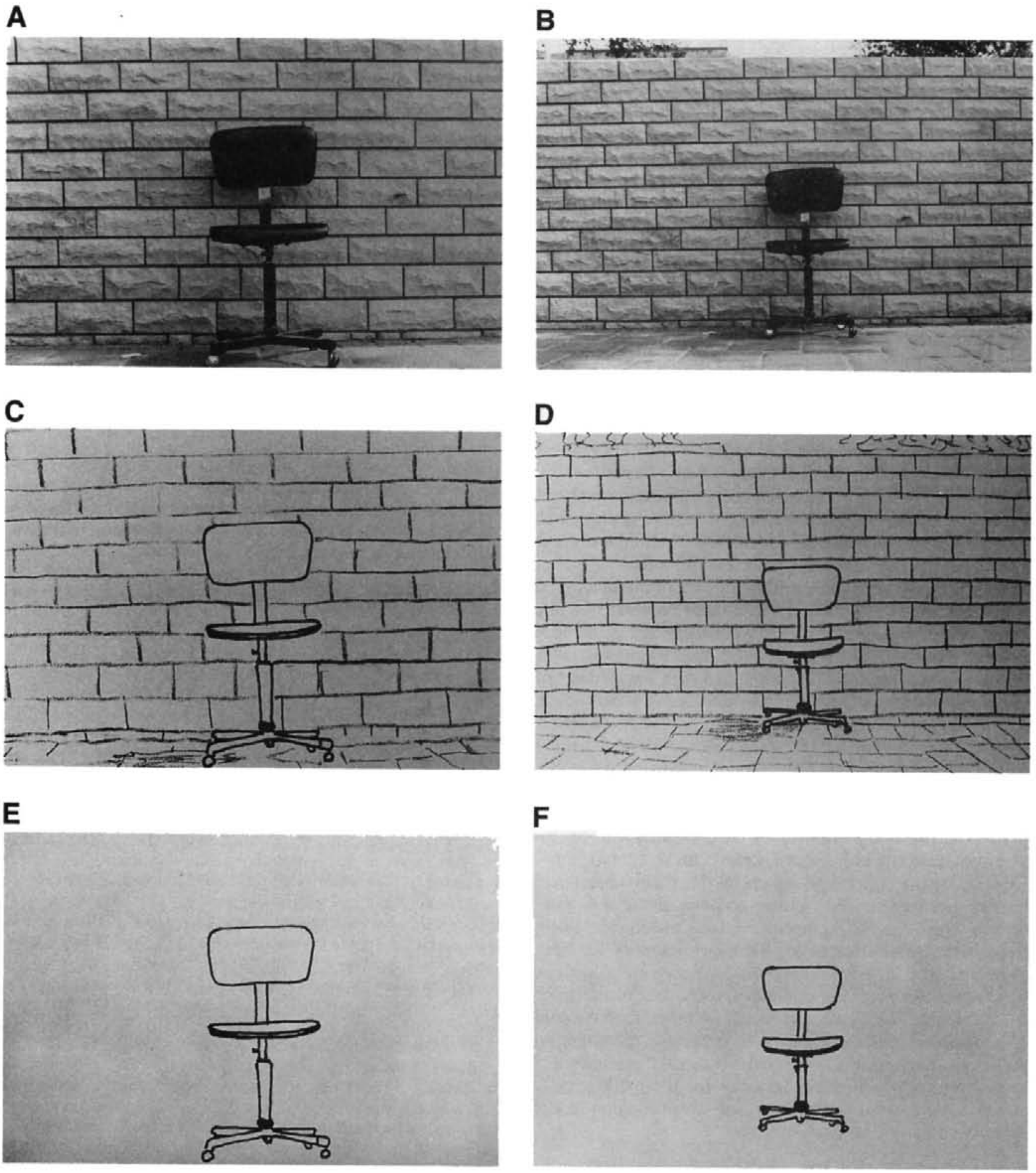

Figure 1. An example of close-up pictures (left column) and wide-angle pictures (right column) from the photograph-scene condition (A and B), the outline-scene condition (C and D), and the outline-object condition (E and F). Note that in the experiment the photograph-scenes were in color.

Results and Discussion

Seven participants (2–3 from each condition) were excluded from the analysis because of missing data.[1] All analyses were then performed on the remaining 134 participants.

Target pictures. To determine if the pictures in each condition tended to be remembered with extended boundaries or restricted boundaries, we obtained the mean boundary ratings for CC and WW targets for each participant. The average of these means for each condition is shown in Table 1. The .95 confidence intervals were determined, and the means that differed significantly from zero are indicated in the table.

For target pictures, a mean boundary rating of 0 (*same*) would signify no directional distortion. A negative mean boundary rating that differs from zero would signify boundary extension because participants would be reporting that the same picture "looks closer-up than before." A positive mean boundary rating that differs significantly from zero would signify boundary restriction because participants would be reporting that the same picture looks "farther away than before."

As may be seen in the table, both scene conditions replicated the pattern of errors obtained in previous research: Close-ups yielded a large degree of boundary extension, and wide-angle pictures yielded no directional distortion. However, in the case of the outline-objects, the pattern was markedly bidirectional. The close-ups yielded boundary extension, and the wide-angle pictures yielded an equal degree of boundary restriction. The fact that the degree of the distortion for the two picture views was equivalent in magnitude but opposite in direction is very important because this is the pattern that one would expect to see if items were normalizing toward the average view in the set. In terms of the extension–normalization model, without the influence of the perceptual schema to cause an overall bias for extension, the primary cause for distortion was normalization. The pattern of errors in the three conditions were systematic and followed the predictions that we had derived from the extension–normalization model.

Table 1
Mean Boundary Rating (Range −2 to +2) and Percentage of "Same" Responses for Close-Up (CC) and Wide-Angle (WW) Target Pictures as a Function of Stimulus Type (Experiment 1)

	CC		WW	
Stimulus type	*M*	*SD*	*M*	*SD*
Mean boundary rating				
Photograph-scene	−.24[a]	.31	.02	.44
Outline-scene	−.41[a]	.41	−.03	.46
Outline-object	−.13[a]	.31	.13[a]	.33
Percentage of "same" responses				
Photograph-scene	59	25	59	30
Outline-scene	57	28	65	29
Outline-object	74	24	74	28

Note. The number of participants in the photograph-scene, outline-scene, and outline-object conditions (following removal of participants with missing data), was 45, 46, and 43, respectively.
[a]Mean differs significantly from zero, as shown by the .95 confidence intervals.

Considering the picture sets as a whole (collapsing over picture view), as in previous research, photograph scenes yielded boundary extension. The mean boundary rating was −.11 ($SD = .25$), which differed significantly from zero (.95 confidence intervals in all three conditions included $M \pm .07$). This was true also for the outlines-scenes, which yielded a mean rating of −.22 ($SD = .26$). In contrast to the two scene conditions, however, memory for outline-objects yielded no directional distortion. The mean boundary rating was zero ($SD = .25$).

To compare the boundary scores across conditions, we conducted single-degree-of-freedom planned comparisons to test the effect of medium on memory for scenes (photograph-scenes vs. outline-scenes), the effect of the presence or absence of scene context on memory for pictures (outline-scenes vs. outline-objects), and the effect of picture view across all three stimulus types (close-up vs. wide-angle views).

In terms of medium, not only did outline-scenes yield the typical boundary extension pattern obtained with photographs but the degree of the distortion was significantly greater for outline-scenes than for photograph-scenes, $F(1, 131) = 4.27$, $MSE = 0.13$, $p < .05$, and there was no interaction of medium with picture view ($F < 1$). This might indicate that viewers rely even more heavily on the perceptual schema when analyzing relatively sketchy outline scenes than when analyzing richly detailed photographs. However, the effect was rather small, and its reliability would have to be addressed in future research.

Not surprisingly, the planned comparisons addressing scene context (outline-scenes vs. outline-objects) showed that the mean boundary ratings in the two conditions differed significantly, $F(1, 131) = 16.74$, $MSE = 0.13$, $p < .001$. There was no interaction between context and picture view ($F < 1$), which simply signifies that although the distortion pattern differed dramatically between the two conditions (i.e., a unidirectional bias for scenes and a bidirectional bias for objects), the boundary scores differed by the same amount along the boundary rating scale. (That is, the .26 difference in the mean ratings of close-up and wide-angle outline-object targets did not differ significantly from the .38 difference in the mean rating of the close-up and wide-angle outline-scene targets.) As usual, across all conditions re-

[1] A participant's data were not used (a) if they contained more than two missing data points or more than one missing data point in a given test condition (e.g., CC pictures), or (b) if there were two missing data points for a particular picture in a given test condition (in which case, one participant was randomly excluded). These criteria were adopted to avoid bias caused by calculating participant and picture means that were based on a very different number of scores. Missing data points included cases in which participants reported not remembering a picture or in which they simply failed to make a response.

sponses to close-up and wide-angle views differed significantly, $F(1, 131) = 37.25$, $MSE = 0.16$, $p < .001$.

Although outline-scenes and outline-objects yielded patterns of results predicted on the basis of the extension–normalization model, two alternate explanations must be addressed. One possibility is that because outline-objects are relatively uncomplicated, they may be remembered extremely well. The lack of a unidirectional distortion of boundaries in this case could simply be an artifact of a ceiling effect. To examine this possibility, participants' ability to correctly recognize target pictures as the "same" in each condition was analyzed. The percentage of correct "same" responses to CC and WW pictures in each condition is shown in Table 1.

As can be seen in the table, participants in all three conditions made a substantial number of errors. The same planned comparisons described earlier were conducted on the number of correct "same" responses. Across conditions, there was no difference in the number of "same" responses to close-up and wide-angle pictures ($F < 1$). The planned comparisons revealed that the medium in which a scene was presented (photograph-scene vs. outline-scene) had no effect on the number of "same" responses ($F < 1$), nor was there an interaction of medium with picture view, $F(1, 131) = 1.13$, $MSE = 0.93$. However, when the planned comparisons between outline-scenes and outline-objects were conducted, they did reveal a significantly greater number of correct "same" responses to the outline-objects than to the outline-scenes, $F(1, 131) = 8.48$, $MSE = 1.48$, $p < .01$, with no interaction between stimulus type and picture view, $F(1, 131) = 1.27$, $MSE = 0.93$. Although spatial expanse was correctly recognized more frequently in the outline-object condition, the level of performance cannot be construed as a ceiling effect, as slightly more than one quarter of all responses in the outline-object condition were erroneous. These errors simply followed a different pattern in the outline-object condition than in the outline-scene condition. As reported earlier, the errors were not random; they yielded the bidirectional pattern of distortion expected to occur when objects normalize toward the average size in the set.

Another alternate explanation of the difference between the outline-scene and outline-object conditions is that a relatively high frequency of guesses in one of the conditions (perhaps due to the different levels of complexity or some related factor) might have had a differential effect on the pattern of errors. However, confidence ratings were similar across conditions. (Note that one participant in the outline-object condition did not provide confidence ratings and was therefore not included in this analysis). Participants reported being "sure," "pretty sure," and "not sure" on 55.3%, 36.3%, and 7.5%, respectively, in the outline-scene condition, and 62.2%, 30.8%, and 5.5%, respectively, in the outline-object condition. They reported they did not remember a picture, or failed to provide either a boundary rating or confidence rating on 1.0% and 1.5%, in the outline-scene and outline-object conditions, respectively.[2] More important, when "not sure" responses were eliminated from the analysis in each condition, the same pattern of results was obtained. Outline-scenes yielded boundary extension ($M = -.25$, $SD = .28$), and outline-objects yielded no directional distortion ($M = -.02$, $SD = .24$; .95 confidence intervals included $M \pm .08$ for outline scenes and $M \pm .07$ for the outline-objects).

Distractor pictures. Mean boundary ratings for the wide-angle (CW) and close-up (WC) distractors in each of the three conditions is shown in Table 2. The .95 confidence intervals were determined, and means that differed significantly from zero are indicated in the table. To test the symmetry of the responses to distractors in the three conditions, the same planned comparisons described earlier were conducted on the absolute value of the mean ratings for CW and WC pictures.

Overall, the magnitude of the boundary ratings was greater for close-up distractors than for wide-angle distractors, $F(1, 131) = 17.29$, $MSE = 0.16$, $p < .001$. As can be seen in Table 2, this difference reflects the response asymmetry in the photograph-scene and outline-scene conditions but not in the outline-object condition, where the responses were identical in magnitude. This difference in response pattern was borne out by the following results. Although there was no effect of scene context (outline-scene vs. outline-object) on the mean ratings obtained ($F < 1$), there was a significant interaction between distractor type (CW vs. WC) and stimulus type (outline-scene vs. outline-object), $F(1, 131) = 11.58$, $MSE = 0.16$, $p < .01$. In contrast, when the stimuli were scenes, the medium of presentation (photograph-scene vs. outline-scene) had no effect on the magnitude of the ratings ($F < 1$), and there was no interaction of the medium of presentation with distractor type, $F(1, 131) = 3.39$, $MSE = 0.16$.

The percentage of "same" responses to distractors followed the same pattern. The percentage of "same" responses to CW and WC distractors was 13 ($SD = 19$) and 8 ($SD = 14$), respectively, in the photograph-scene condition, 11 ($SD = 16$) and 4 ($SD = 10$), respectively, in the outline-scene condition, and 6 ($SD = 13$) and 7 ($SD = 14$), respectively, in the outline-object condition. The same planned comparisons were conducted on these data and showed that, overall, the mean number of "same" responses was greater for CW than for WC distractors, $F(1, 131) = 4.97$, $MSE = 0.29$, $p < .05$. Once again, this appears to be caused by the response pattern in the scene conditions. As before, the planned comparisons that addressed scene context revealed no main effect of scene context (outline-scene vs. outline-object; $F < 1$); however, in this case, the interaction between distractor type and scene context approached but did not reach significance, $F(1, 131) = 3.13$, $MSE = 0.29$, $p = .08$. The planned comparisons addressing the medium in which the scenes were presented (photograph-scene or outline-scene) showed that it did not affect the number of false "same" responses, $F(1, 131) = 1.30$, $MSE = 0.40$, and that there was no interaction of medium of presentation with distractor type ($F < 1$).

[2] As a point of comparison, in the photograph-scene condition, participants reported being "sure," "pretty sure," and "not sure" on 51.1%, 38.9%, and 8.6% of the trials, respectively. They did not provide a confidence rating on 1.4% of the trials.

Table 2
Mean Boundary Rating (Range −2 to +2) for Wide-Angle (CW) and Close-Up (WC) Distractors as a Function of Stimulus Type (Experiment 1)

	CW		WC	
Stimulus type	*M*	*SD*	*M*	*SD*
Photograph-scene	1.25[a]	0.41	−1.44[a]	0.38
Outline-scene	1.18[a]	0.47	−1.58[a]	0.33
Outline-object	1.43[a]	0.36	−1.43[a]	0.32

[a]Mean differs significantly from zero, as shown by the .95 confidence intervals.

Experiment 2

In Experiment 2, participants were asked to draw outline-objects or outline-scenes from memory. The purpose was to determine if the results of Experiment 1 would be replicated by using a different test procedure. A comparison of recognition and recall is important because there are many situations in which these methods of testing memory yield different results (e.g., Flexser & Tulving, 1978; Johnson, 1983). If boundary extension is a fundamental aspect of the pictorial representation, we would expect to see the same pattern results in both recognition and recall.

To provide a quantitative assessment of spatial memory based on the drawings, we measured the area of the main object in each drawing and compared it to the area of the main object in the stimulus. If the objects were drawn as covering a smaller area of the picture space, this would indicate boundary extension. If they were drawn as covering a larger area, this would indicate boundary restriction. If, on average, they were drawn as covering the same area, then this would indicate no directional distortion.

Method

Participants. Participants were 114 undergraduates from the same population described in Experiment 1.

Stimuli. There were two stimulus types: outline-scenes and outline-objects. There were 16 scenes, 9 of which were the same as in Experiment 1. Close-up and wide-angle versions of each scene were created, yielding 32 outline-scenes. As in Experiment 1, outline-objects were created by tracing the main object in each scene onto a blank background. A description of the new picture set is provided in Appendix B.

Apparatus. The apparatus and the arrangement of chairs was the same as in Experiment 1, except that the chairs were positioned a few inches farther from the screen. The distance of the screen from the front, center, and back rows was 81, 126, and 168 inches, (2.06, 3.20, 4.27 m), respectively. The approximate visual angles for participants sitting in the center of the front and back rows were 16° × 11° and 8° × 5°, respectively.

Design and procedure. Participants took part in one of two conditions: outline-scene or outline-object. They were presented with eight close-ups and eight wide-angle views. Picture view was counterbalanced across participants such that each specific scene (or outline-object) was presented as a close-up or wide-angle view, equally often. As in Experiment 1, no more than three consecutive pictures were shown in the same view. Following presentation, a recall test was administered. Eight of the scenes (or outline-objects) were selected for recall and were designated by name in the participants' response booklets. Half had been presented as wide-angle views during presentation and half as close-ups. The pictures were chosen such that two close-up views and two wide-angle views were from the first half of the presentation sequence and two of each view were from the second half, regardless of which counterbalancing sequence the participant had viewed.

Response booklets contained eight rectangles that had the same aspect ratio as the stimuli (1:1.5). These were 4 in. × 6 in. in size (approximately 10 cm × 15 cm). The label describing each of the eight pictures to be recalled appeared above each rectangle. The participants were instructed to draw each of these pictures within its designated rectangle. They were asked to consider the edges of the rectangle to be the same as the edges of the picture on the screen and to draw their pictures accordingly. They were instructed to try to draw each picture in as much detail as possible and to pay attention to the size and position of objects in the picture space.

Analyzing the drawings. To provide a quantitative analysis of the participants' drawings, it was necessary to measure the area of the main object in each stimulus and the area of the main object in each of the participants' drawings. Each stimulus was projected onto a 4 in. × 6 in. (10 cm × 15 cm) rectangle and the external perimeter of the main object was traced. These contours were then digitized with a Japan Victor Corporation (JVC) CCD color video camera, using an Intel 386, 25-MHZ IBM-compatible computer with a four-megabyte Truevision AtVista graphics board and a 13-in. Mitsubishi color monitor (Model FA3415ATK). The area of each object was calculated by an area estimation program that converted pixels into area measurements described in square tenths of an inch (which corresponds to the grid sheets used in earlier research, in which area was manually estimated; Intraub, 1992; Intraub & Berkowits, 1996).

The external perimeters of the main objects in each of the participants' drawings were also traced with black ink inside 4 in. × 6 in. (10 cm × 15 cm) rectangles. They were digitized and analyzed in the same manner described earlier. For each drawing, the area of the main object in the participant's drawing was divided by the area of the main object in the stimulus, yielding what we call the *proportion drawn.*

A mean proportion drawn of 1.00 would indicate that, on average, the area drawn was the same as the actual area of the object, thus indicating no directional distortion. A mean proportion drawn that is significantly less than 1.00 would indicate that the drawn objects tended to cover a smaller area than the actual objects, thus indicating boundary extension. A mean proportion drawn that is significantly greater than 1.00 would indicate that the drawn objects tended to cover a larger area than the actual objects, thus indicating boundary restriction.

Results and Discussion

Participants' drawings yielded a pattern of boundary errors that mirrored the pattern obtained for outline-scenes and outline-objects in Experiment 1.

Treatment of missing data. Missing data occurred either because a participant failed to draw a picture or because the area of the main object in the drawing was greater than three standard deviations from the mean proportion drawn for that picture. Data were analyzed only for those participants who had no missing data. This procedure was followed because the objects differed greatly in size and shape, factors which might influence the way participants would draw a particular object. To avoid any bias that the exclusion of a particular picture might exert on a participant's mean, we decided, a priori, that all participants' means must be based on the same set of eight pictures. Based on this criterion, 4 participants from the outline-object condition and 13 participants from the outline-scene condition were excluded from the analysis because of missing drawings, and 4 participants from each condition were excluded because of outliers. This left a total of 89 participants with full sets of data (44 in the outline-object condition and 45 in the outline-scene condition).

Recall. Memory for the size of the main objects differed as predicted, depending on whether the participants had viewed outline-objects or outline-scenes. The mean proportion drawn for both picture views in each condition is shown in Table 3. The .95 confidence interval was calculated for each mean; those that differed significantly from 1.00 are indicated in the table. Consistent with the perceptual schema hypothesis, in the scene condition there was a relatively large reduction in the size of the main object (signifying boundary extension), and there was no significant directional distortion in the wide-angle drawings. In contrast, in the outline-object condition, objects in close-up pictures were drawn as being smaller than before, and objects in the wide-angle pictures were drawn as being larger than before. Once again, the pattern of errors in the outline-object condition was notably symmetrical, suggesting normalization.

Collapsing over picture view, outline-scenes were drawn with extended boundaries. The mean proportion drawn was .82 (SD = .25), and this proportion differed significantly from 1.00 (the .95 confidence interval included $M \pm .07$). In contrast, there was no directional distortion in the drawings of outline-objects. The mean proportion drawn was .96 (SD = .29), which did not differ from 1.00 (the .95 confidence interval included $M \pm .09$).

To compare the degree of the distortion across conditions, a 2 × 2 mixed analysis of variance (ANOVA; Stimulus Type × Picture View) showed that the proportion drawn was greater in the outline-object condition than in the outline-scene condition, $F(1, 87) = 6.06$, $MSE = 0.15$, $p < .05$, and was greater for wide-angle views than for close-ups, $F(1, 87) = 129.12$, $MSE = 0.10$, $p < .001$. There was no interaction of stimulus types and picture view ($F < 1$). This simply signifies that the difference of .56 between the mean proportion drawn for close-ups and wide-angle views in the outline-scene condition did not differ from the .50 difference in the outline-object condition. The lack of a difference, of course, does not address the critical issue of the direction of the distortion (i.e., whether an object is drawn as being larger or smaller than the stimulus-object).

Table 3
Mean Proportion Drawn for Close-Up and Wide-Angle Picture Views as a Function of Stimulus Type (Experiment 2)

Stimulus type	Close-up M	Close-up SD	Wide-angle M	Wide-angle SD
Outline-scene	0.54[a]	0.20	1.10	0.39
Outline-object	0.71[a]	0.21	1.21[a]	0.50

Note. The number of participants in the outline-scene condition and the outline-object condition (following removal of participants with missing data) was 45 and 44, respectively.
[a]Mean differs significantly from 1.00, as shown by the .95 confidence intervals.

Experiment 3

The primary question addressed in Experiment 3 was derived from the premise that visual perception and visual imagination share common representational mechanisms (e.g., Farah, 1988; Finke, 1980, 1985; Shepard, 1984). If the perceptual schema is a representation of expected scene structure, perhaps it can be activated not only by the presentation of a partial view but through the imagination of that view. This possibility is consistent with Shepard's (1984) proposal of resonant modes: mental representations that may resonate or become activated by either top-down or bottom-up stimulation.

To determine if activation of the perceptual schema can be achieved through the top-down route of imagination, participants were presented with the outline-objects used in Experiment 2. The control group received the same instructions as in the previous experiments. The experimental group also received those instructions, however, in addition, they were provided with a description of the photograph from which each object had been traced. They were instructed to "project an image" of the scene onto the outline-object while they studied it.

If the perceptual schema can only be activated by the physical presentation of a partial view, then the pattern of errors should be the same in both conditions and should replicate the outline-object condition in Experiment 1. On the other hand, if imagination can serve to activate the perceptual schema during encoding, then the pattern of boundary recognition errors should differ between the control and imagine-scene conditions. The control condition should yield no directional distortion or a normalization pattern, whereas the imagine condition should yield the asymmetrical pattern predicted by the perceptual schema hypothesis. In the imagine-scene condition, the results should replicate those obtained for the outline-scenes in Experiment 1, even though the stimuli are, in fact, outline-objects.

Method

Participants. Participants were 137 undergraduates (72 women and 65 men) from the same population described in the previous experiments.

Stimuli and apparatus. The same 16 outline-objects and the same apparatus and viewing conditions were used as in Experiment 2.

Design and procedure. Participants took part in one of two conditions: control ($N = 68$) and imagine-scene ($N = 69$). As in Experiment 1, half of the pictures (outline-objects) were presented in the close-up view and half in the wide-angle view, counterbalanced across participants. In both conditions, participants were instructed to remember each outline-object in as much detail as possible, including the size and location of the object in the picture space. They were told to try to retain an "exact copy" of the picture in memory. The only difference between the control and the imagine-scene conditions was that the participants in the imagine-scene condition received this additional instruction:

> Each outline drawing was traced from color photographs of scenes. While you are looking at each outline drawing, I will describe the photograph it was traced from. Use your imagination and try to project this description onto the picture space, so that in your "mind's eye" you can almost "see" the original photograph.

To aid participants' understanding of what we meant by "project this description," we gave them the following demonstration. A sample outline-object was presented on the screen, and a description of the photograph from which it had been traced was read. The actual photograph was then superimposed on the outline-object by using another channel of the tachistoscope. Participants were told that this was a physical demonstration of what we wanted them to do mentally. The final statement in the instructions in both conditions was a reminder to remember the size and location of each object in the picture space. For the control participants, the room was quiet during the 15-s presentation of each slide. For the imagine-scene group, the experimenter described each scene during the 15-s stimulus presentation interval. For example, we described the stimulus shown in Figure 1 as "a black office chair on a stone walkway in front of a large stone wall that fills the picture space." Pretesting allowed us to edit the descriptions so that they could easily be read within the interval.

The same recognition test procedure was used as in Experiment 1, except that participants had 15 s to make their ratings. Half of the pictures were presented in the same view as before (target pictures) and half in the other view (distractor pictures), resulting in four test conditions: CC, WW, CW, and WC. Following the experiment, participants in the imagine-scene condition were asked to write a sentence indicating whether they were able to imagine the color scenes. These self-reports fell into one of three categories: Participant could imagine all scenes, could imagine only some scenes, or could not imagine any of the scenes.

Results and Discussion

Four participants in the control condition and 3 in the imagine-scene condition were excluded from the analysis because of missing data.[3]

Target pictures. The mean boundary rating for close-up and wide-angle targets in each condition are presented in Table 4. The .95 confidence intervals were determined, and any mean that differed significantly from zero is indicated in the table. In the control condition, neither close-up targets (CC) nor wide-angle targets (WW) yielded a significant directional distortion. It is interesting to note, however, the tendency toward a normalization pattern like that obtained in the outline-object condition of Experiment 1. In contrast, the pattern of errors obtained in the imagine-scene condition followed that obtained for the scene stimuli in Experiment 1:

Table 4
Mean Boundary Rating (Range −2 to +2) and Percentage of "Same" Responses for Close-Up (CC) and Wide-Angle (WW) Target Pictures in the Control and Imagine-Scene Conditions (Experiment 3)

Condition	CC *M*	CC *SD*	WW *M*	WW *SD*
Mean boundary rating				
Control	−.06	.27	.04	.25
Imagine-scene	−.40[a]	.31	−.02	.30
Percentage of "same" responses				
Control	78	26	73	24
Imagine-scene	60	28	67	23

Note. The number of participants in the control condition and the imagine-scene condition (following removal of participants with missing data) was 64 and 66, respectively.
[a]Mean differs significantly from zero, as shown by the .95 confidence intervals.

Close-ups yielded a large, significant degree of boundary extension, and wide-angle views yielded no directional distortion.

Collapsing over picture view, the control condition yielded no directional distortion. The mean boundary rating was −.01 (SD = .20), which did not differ from zero (the .95 confidence interval included $M \pm .05$ in both conditions). In contrast, memory for the same stimuli in the imagine-scene condition yielded a significant degree of boundary extension, with a mean rating of −.22 (SD = .21).

A 2 × 2 mixed ANOVA (Condition × Picture View) on the mean boundary scores showed that the mean boundary rating in the imagine-scene condition differed significantly from the mean rating in the control condition, $F(1, 128) = 31.43$, $MSE = 0.09$, $p < .001$, and that boundary rating for close-ups differed significantly from that obtained for wide-angle views, $F(1, 128) = 49.35$, $MSE = 0.08$, $p < .001$. A significant interaction between condition and picture view was obtained, $F(1, 128) = 15.78$, $MSE = 0.08$, $p < .001$.

These observations follow the predictions of the model. However, as discussed previously, they might also be obtained if memory for the objects in the control condition was so good that it approached the ceiling, resulting in so few errors that a unidirectional distortion could not be detected. To evaluate this possibility, as in Experiment 1, we analyzed the number of correct "same" responses in each condition. The percentage of correct "same" responses for CC and WW targets in each condition is shown in Table 4.

A 2 × 2 mixed ANOVA (Condition × Picture View) on the number of same responses in each condition showed that participants did indeed make more correct "same" responses in the control condition than in the imagine-scene condition, $F(1, 128) = 12.51$, $MSE = 1.22$, $p < .01$. However, the number of correct responses in the control

[3] Exclusion of participants from the analysis followed the same criteria as in Experiment 1 (see footnote 1) except that, because there were so many more participants, criterion b was not applied.

condition was clearly not at ceiling. On average, participants did not recognize the target as such 25% of the time. There was no effect of picture view ($F < 1$). There was a significant interaction of condition and picture view, $F(1, 128) = 4.17$, $MSE = 0.82$, $p < .05$, although there is no obvious theoretical significance to this pattern of responses (see Table 4).

As in Experiment 1, the possibility that different levels of guessing in the control and imagine-scene conditions might have had a differential effect on the pattern of errors was addressed by analyzing the confidence ratings. Overall confidence in the responses was relatively high in both conditions and the percentages of each level were very similar. Participants reported being "sure," "pretty sure," or "not sure" 63.0%, 31.3%, and 4.8% of the time in the control condition, and 56.1%, 35.3%, and 7.1% of the time in the imagine-scene condition. (They reported not remembering a picture, or they failed to provide either a boundary rating or confidence rating on 1.0% and 1.5% of the trials in the control and imagine-scene conditions, respectively.) A reanalysis of the data following removal of all "not sure" responses did not change the pattern of results. No directional distortion was obtained in the control condition ($M = -.01$, $SD = .20$), and boundary extension was obtained in the imagine-scene condition ($M = -.26$, $SD = .25$; the .95 confidence interval included $M \pm .05$ and $M \pm .06$, respectively).

Distractor pictures. Responses to distractor items indicated that the size of the outline-objects was remembered differently when participants were instructed to imagine a scene and when they were not. Table 5 shows the mean boundary ratings for wide-angle (CW) and close-up (WC) distractors in the two conditions. The .95 confidence intervals were determined, and the means that differ significantly from zero are indicated in the table.

As may be seen in Table 5, in the control condition the magnitude of the boundary ratings for the close-up distractors and wide-angle distractors yielded a symmetrical response pattern. This replicated the pattern obtained for outline-objects in Experiment 1. In contrast, in the imagine-scene condition, boundary ratings yielded the asymmetrical pattern that is diagnostic of boundary extension. Participants tended to rate the wide-angle distractors as looking more like their memory for the target than they rated the close-up distractors.

To contrast the magnitude of the boundary ratings to the CW and WC distractors in each condition, the absolute value of the ratings was analyzed in a 2 × 2 mixed ANOVA (Condition × Distractor Type). There was no main effect of condition ($F < 1$). However, there was a significant main effect of distractor type, $F(1, 128) = 9.34$, $MSE = 0.10$, $p < .01$, and a significant interaction between condition and distractor type, $F(1, 128) = 6.04$, $MSE = 0.10$, $p < .05$, reflecting the asymmetrical response pattern obtained in the imagine-scene condition and the symmetrical pattern obtained in the control condition.

Table 5
Mean Boundary Rating (Range −2 to +2) for Wide-Angle (CW) and Close-Up (WC) Distractors in the Control and Imagine-Scene Conditions (Experiment 3)

Condition	CW *M*	CW *SD*	WC *M*	WC *SD*
Control	1.68[a]	0.30	−1.71[a]	0.36
Imagine-scene	1.58[a]	0.34	−1.80[a]	0.23

[a]Mean differs significantly from zero, as shown by the .95 confidence intervals.

Memory as a function of imagery self-report. In the event that we did not obtain a perceptual schema effect in the imagine-scene condition, we wanted to have some data that would inform us as to whether participants felt they actually could imagine the scenes. If many participants reported having difficulty, we planned to separately analyze the responses of any participants who claimed they could do the task. For this reason we asked for the imagery self-report at the end of the experiment. As it turned out, the perceptual schema effect was obtained. However, we still analyzed the data for those participants who claimed they could always do the task. The majority of participants ($N = 46$) fell into this category. (Of the remaining participants, 11 said they could sometimes imagine the scenes and 3 said that they could not imagine the scenes.)

The analysis yielded the same pattern of results that had been observed for the group as a whole. Overall, there was a significant degree of boundary extension ($M = -.23$, $SD = .21$). The mean boundary ratings for these participants as a function of test condition are shown in Table 6. What is interesting is that the perceptual schema effect appeared to be somewhat stronger for these participants in that, in addition to the close-ups yielding boundary extension, a small, significant boundary extension effect was obtained for the wide-angle pictures (see Table 6). Analysis of the absolute values of the mean boundary ratings to the distractors yielded the expected response asymmetry, $t(45) = 3.53$, $p < .01$.

Experiment 4

The purpose of Experiment 4 was to determine if an imagination task per se is what caused participants in the imagine-scene condition of Experiment 3 to remember spatial expanses differently than in the control condition, or if it was the activation of expectations regarding continuous scenes that was the cause. In Experiment 4, as in the imagine-scene condition, participants viewed the outline-objects and were asked to remember the size and placement of each one. However, in this case, rather than imagining scene structure, the participants were instructed to imagine each object in the colors specified by the experimenter.

If the addition of a concurrent imagination task is what caused the outline-objects in Experiment 3 to "behave" like scenes, then the same pattern would be expected to occur following the imagine-color task. If, however, it was the imagination of scene structure that caused the distortion pattern to change, then imagining the outline-objects in color should yield the pattern predicted for nonscenes and

Table 6
Mean Boundary Ratings for Participants Who Reported They Could Always Imagine the Required Details (Experiments 3 and 4)

Imagery instruction	CC	WW	CW	WC
Imagine-scene (Exp. 3)				
M	−0.37[a]	−0.09[a]	1.62[a]	−1.83[a]
SD	0.32	0.26	0.32	0.23
Imagine-colors (Exp. 4)				
M	−0.16[a]	+0.14[a]	1.52[a]	−1.58[a]
SD	0.33	0.34	0.48	0.57

Note. For imagine-scene condition, $N = 46$; for imagine-colors condition, $N = 48$. CC = close-up target picture; WW = wide-angle target picture; CW = close-up distractor; WC = wide-angle distractor; Exp. = Experiment.
[a]Mean differs significantly from zero, as shown by the .95 confidence intervals.

thus replicate the recognition memory results of the nonscene conditions in Experiments 1 and 3.

Method

Participants. Participants were 81 undergraduates (47 women and 34 men) from the same population described in the previous experiments.

Stimuli and apparatus. The same 16 outline-objects and the same apparatus and viewing conditions were used as in the previous experiments.

Design and procedure. As in Experiment 1, half of the outline-objects were presented in the close-up view and half in the wide-angle view, counterbalanced across participants. The same instructions were given as in the imagine-scene condition of Experiment 3, with the following exception. Instead of describing a scene for the participant to mentally project onto the picture, the experimenter described the objects' colors. Using the example of the office chair (see Experiment 3, *Design and procedure*), we described the stimulus shown in Figure 1 as an office chair with a black seat and back, and shiny aluminum-colored legs and wheels.

The same recognition test procedure was used as in Experiment 3. Half of the pictures were presented in the same view as before (target pictures) and half in the other view (distractor pictures), resulting in four test conditions: CC, WW, CW, and WC. Following the experiment, participants were asked to write a sentence indicating whether or not they were able to imagine the objects in color.

Results and Discussion

Target pictures. Imagining the outline-objects in color did not cause them to yield the error pattern predicted for scenes. The pattern of errors replicated those obtained in the previous nonscene conditions. The mean boundary rating for close-up and wide-angle targets was −.13 (SD = .33) and .14 (SD = .32), respectively. The .95 confidence intervals showed that both scores differed significantly from zero ($M \pm .07$ for both close-up and wide-angle targets). Close-up objects yielded boundary extension, and wide-angle objects yielded boundary restriction. The degree of the distortion was almost identical. Collapsing over picture view, the mean boundary rating for the set was .01 (SD = .23), which did not differ from zero (.95 confidence interval, $M \pm .05$).

As in Experiments 1 and 3, there was no evidence that a ceiling effect was obscuring the results. The percentage of correct "same" responses for CC and WW targets was 72% (SD = 26) and 68% (SD = 25), respectively. Participants made many errors regarding spatial expanse. However, as discussed previously, these errors were bidirectional.

Confidence in the responses was relatively high. Participants reported being "sure," "pretty sure," or "not sure" 65.9%, 30.2%, and 3.1% of the time, respectively. (They reported not remembering a picture, or they failed to provide either a boundary rating or confidence rating on 0.8% of the trials.) As in Experiments 1 and 3, even when responses labeled as "not sure" were eliminated from the analysis, responses still yielded no directional distortion. The mean boundary rating was zero (SD = .24).

Distractor pictures. Responses to the two distractor types were clearly symmetrical. The mean boundary ratings for wide-angle (CW) and close-up (WC) distractors was 1.52 (SD = .52) and −1.55 (SD = .62), respectively. A t test comparing the absolute values of the mean boundary ratings showed no significant difference between them, $t(80) = .64$. As in Experiment 3, the number of false "same" responses was negligible, ranging from 2% to 3%.

Memory as a function of imagery self-report. All but 9 participants provided imagery self-reports, and these were sorted into the same three categories as in Experiment 3. The majority reported being able to imagine the colors on each trial ($N = 48$). (Of the remaining participants, 16 claimed they could imagine the colors only some of the time, and 8 reported that they could not imagine the colors.) As in Experiment 3, we conducted a separate analysis for those who claimed they could always do the task. The mean boundary ratings for those participants are shown in Table 6.

Participants' responses clearly mirrored those obtained for the control condition in Experiment 3 (which did not contain an imagery instruction). As may be seen in the table, CC pictures yielded boundary extension and WW pictures yielded a similar degree of boundary restriction. Collapsing over picture view, there was no directional distortion (the mean boundary rating was −.01, SD = .29). Responses to the distractors (CW and WC) were symmetrical: The absolute value of the mean ratings to each did not differ, $t(47) = 1.07$. A visual imagination task that involved color rather than scene structure clearly did not yield the perceptual schema effect.

General Discussion

As the viewer scans a continuous visual environment, input to the visual system is delivered through a succession of partial views. Hochberg (1978, 1986) has proposed that a mental schema of expected spatial layout serves to guide comprehension and integration of these successive views. We propose that the same schema, which we have referred to as the *perceptual schema,* is a fundamental representation that underlies not only perception of scenes but memory and imagination of scenes as well. Four experiments, conducted within the framework of our extension–normalization model (e.g., Intraub et al., 1992; Intraub et al., 1996), provide support for this hypothesis.

On the basis of the model, we predicted that spatial memory for pictures of objects should differ depending on whether the picture depicts a partial view of a continuous scene. Presentation of a scene context would be expected to activate the observer's perceptual schema—a visuospatial representation of the anticipated layout of the scene just beyond the picture's boundaries. Aspects of the anticipated area would become incorporated in the observer's mental representation, thus yielding boundary extension. Pictures that do not depict a partial view of a scene (e.g., outline object on a blank background) would not be expected to activate the schema, and therefore no directional distortion would be predicted for the set as a whole. On the basis of the model's tenets, however, if any consistent distortion were to be obtained, the distortion would be expected to reflect normalization (i.e., regression toward the average view). Large objects would be remembered as smaller and small objects would be remembered as larger as the objects normalize toward the average in the set, yielding a symmetrical error pattern.

Consistent with these predictions, within minutes of presentation, spatial memory for pictures of objects in scenes and pictures of the same objects on blank backgrounds differed in the predicted manner. A pattern of errors consistent with a unidirectional distortion was obtained for the pictures of scenes, whereas a normalization pattern was obtained for the pictures of objects. This difference emerged when memory was tested by using a recognition procedure (Experiment 1) and then again, when memory was tested by using a drawing task (Experiment 2). For the outline-scenes, memory for the set as a whole yielded boundary extension. When the responses were analyzed as a function of picture view, close-ups yielded boundary extension and wide-angle views yielded no directional distortion. This is the pattern that has been reported for photographs of scenes (Experiment 1; Intraub et al., 1992, 1996; Intraub & Berkowits, 1996; Intraub & Richardson, 1989).

In contrast, when the outline-objects were presented on blank backgrounds, no overall directional distortion of spatial memory was obtained. When the data were analyzed as a function of picture view, close-ups yielded a relatively small extension error (in that objects were remembered as covering less of the picture space), and wide-angle views yielded an equivalent degree of boundary restriction (in that objects were remembered as having covered a greater portion of the picture space). This symmetrical pattern of distortion is the expected consequence of normalization.

Responses to distractor pictures provided converging evidence that the spatial representation of pictures depicting objects in scenes, and those depicting objects alone, differ. For outline-scenes, the response asymmetry to wide-angle and close-up distractors that is diagnostic of boundary extension was obtained. Wide-angle distractors tended to be rated as looking more like the stimulus picture than did close-up distractors. In contrast, in the outline-object condition, responses to the two types of distractors were symmetrical, indicating that there was no unidirectional distortion of the remembered representation.

Imagination

It is important to remember that scenes were never shown in either the presentation or the test phase of the imagine-conditions in Experiments 3 and 4, and that in both conditions participants viewed the same set of stimuli (outline-objects). The pattern of errors, with respect to whether the same objects were remembered as being larger or smaller, differed in the ways predicted by the model, depending on whether participants imagined a scene context or not. When there was no imagination task (control condition in Experiment 3) or when the imagination task required participants to imagine the objects in color (Experiment 4), the pattern of errors made when they rated targets and when they rated distractors replicated those obtained with outline-objects in Experiment 1. When participants imagined scenes (Experiment 3), responses to the same targets and distractors replicated the pattern obtained for scenes.

These results support the hypothesis that the act of imagining a partial view involves activation of a perceptual schema, just as does the act of perceiving a partial view. Regardless of whether perception or imagination initiates the activation, boundary extension occurs. The results of the imagine-color condition indicate that in the imagine-scene condition (Experiment 3), it is not imagination per se that caused the results to replicate those obtained for scenes but an imagination task that necessitated access to knowledge of expected scene structure.

This provides a new area in which visual perception and visual imagery seem to share common processes. The task is relatively immune to the problems of tacit knowledge and experimenter bias that have been raised with respect to some paradigms, particularly those that ask observers to "act as though" they were perceiving during an imagery task (see Farah, 1988; Finke, 1980, 1985; Intons-Peterson, 1983). In our imagery experiments, the observer's primary task was to remember the size and location of objects. The imagery task was incidental. The predicted outcome was complex and nonintuitive involving different responses to close-up and wide-angle pictures. Because picture view was a within-subject variable and only a single instruction was given, it is unlikely that the results were caused by experimenter bias. The results are consistent with the hypothesis that perception and imagination share a common representation and that activation of this representation yields a predictable bias in memory.

Reisberg (1996) has offered a similar argument about perception and imagination. In his recent account of why visual images are sometimes not subject to reinterpretation (as in Chambers & Reisberg, 1985), he argues that both visual images and percepts are uneven in terms of the density of information available to the observer at a given moment in time (e.g., see Hochberg, 1981; Rock, 1983) and that both are understood within a frame of reference.

Perception and imagination, in this sense, share common properties (see also Intons-Peterson, 1996; Intons-Peterson & McDaniel, 1991). The current experiments suggest that they may share access to a common representation as well.

Defining a Scene

We have raised the possibility that activation of the perceptual schema requires a partial view of a scene (perceived or imagined). However, we have not yet provided a principled definition of what constitutes a "scene." Biederman's seminal work on scene perception (see Biederman, 1981) has provided a framework for analyzing scene structure. He proposed that when objects and backgrounds are arranged in accord with five relational rules, together they will constitute a "well-formed scene." However, in terms of our predictions, the question is not so much what constitutes a well-formed scene as what *minimum* visuospatial relations are necessary for a display to be treated as a scene by the visual system. Biederman's framework provides a reasonable entry-point for considering this question.

Biederman's rules involve the relationships of objects and backgrounds in the following terms: (a) probability (the likelihood that a given object would normally appear in such a scene), (b) support, (c) size, (d) interposition (objects typically occlude the background), and (e) location (objects have expected locations within a meaningful scene). We chose pictures of outline-objects to provide the first test of our hypothesis regarding nonscenes because these displays are impoverished in terms of all five of Biederman's (1981) proposed relational rules (see Biederman, Blickle, Teitelbaum, & Klatsky, 1988, for a related example of objects in nonscene displays). There is no depiction of relative size, probability, location (the background is blank and nonrepresentative), support, or interposition (the object does not occlude a surface). It is not clear if all five must be violated to prevent the automatic activation of the perceptual schema, but there is evidence that violation of probability alone is not sufficient. Scenes undergoing what Biederman would call a "probability violation" (Biederman, 1981; Biederman, Mezzanotte, & Rabinowitz, 1982) were used by Intraub and Bodamer (1993; Figures 1 and 2). These included photographs of "bananas on a rock pile" and "a light bulb on grass." Viewers had no difficulty understanding these somewhat unusual scenes, and when they were retrieved from memory, they were remembered with extended boundaries.

In terms of our formulation, the fact that violation of a probability relation does not eliminate boundary extension makes sense. The perceptual schema is not viewed as a script or a list of probable elements. It is envisioned to be a representation of expected spatial layout. In a similar vein, it is not simply that the outline-objects have a plain background that prevents them from being interpreted as scenes. It is that the background does not represent anything—it is simply the paper the representation is drawn on. One can have an object on a plain background but still have a scene, as in the case of some of the photographs that have been used in boundary extension research (e.g., a compact disk on a red piece of poster board; Intraub et al., 1992). The background, although plain, is a real surface that is understood to continue beyond the picture's boundaries.

At this point we tentatively suggest that to be a scene a picture must at least represent a surface or location in real space. The extent to which various relations added to a picture of an outline-object might suddenly evoke a scene is not yet clear. For example, perhaps simply presenting a filled object (with texture and shading) would evoke a scene because it would occlude the background (interposition) and give the sense of a surface, or perhaps interposition alone would not be enough. This is an empirical question that has yet to be addressed. A picture that represents a background surface or location would, by definition, depict a partial view of a continuous layout and activate the schema. Activation of the schema may involve several levels of information, from relatively low-level (as in the case of amodal completion; e.g., see Nakayama, He, & Shimojo, 1995) to relatively high-level conceptual information about the nature of surfaces and objects in the scene.

In conclusion, we propose that boundary extension may be the natural result of a system that has evolved to allow the viewer to understand a continuous visual world based on partial views. It would be economical for such a system to treat all partial views in the same way, regardless of whether their source is a glimpse of the visual world, a photograph, an outline drawing, or a creative act of imagination.

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Appendix A

Scenes Used in Experiment 1

Office chair on sidewalk in front of a stone wall
Vacuum in the corner on a tile floor
Rocking horse on grass in front of trees and a building
See-saw on sand in front of a multi-colored fence and a tree
Public telephone on street corner in front of a tree
Old cannon on platform in front of a building
Car in front of fence, trees and houses
Dictionary on a wood floor
Hair dryer on a brick patio
Bananas on a rock pile
Lawn chair on a dry, grassy field
Lantern hanging on a log cabin wall
Dust pan on a tile floor
Basketball on a gym floor in front of a cinder block wall
Traffic cone on asphalt
Soda can on gravel in front of rocky wall

Appendix B

Scenes Used in Experiment 2

Dust pan on tile floor
Basketball on a gym floor in front of a cinder block wall
Soda can on gravel in front of rocky wall
Car in empty parking lot in front of trees
Music stand on wood floor in front of white acoustic tile wall
A spool of thread on a wooden shelf attached to a yellow wall
Office chair on sidewalk in front of a stone wall
Exit sign hanging from ceiling tile
Swiss army knife on a slate patio
Portable radio/cassette player on wood chips
Hair dryer on a brick patio
Lawn chair on a dry, grassy field
Man sitting on concrete floor in front of a red brick wall
Dictionary on a wood floor
Bananas on a rock pile
Traffic cone on asphalt

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