Journal of Experimental Psychology:
Human Perception and Performance
2002, Vol. 28, No. 3, 589–599

Copyright 2002 by the American Psychological Association, Inc.
0096-1523/02/$5.00 DOI: 10.1037//0096-1523.28.3.589

Surface Construal and the Mental Representation of Scenes

Carmela V. Gottesman and Helene Intraub
University of Delaware

What distinguishes scenes from nonscenes? Photographs of objects on both naturalistic and blank backgrounds yielded boundary extension (BE: memory for unseen spatial expanse outside the picture's boundaries). However, line-drawn objects on blank backgrounds did not (Experiment 1). Perhaps the blank background was construed as depicting a real-world surface in the photograph condition but was construed as depicting nothing in the line-drawn condition. To change background construal, the authors used objects cut out of photographs; these were placed on blank backgrounds while viewers watched (Experiments 2 and 3). BE was eliminated. The authors propose that amodal continuation is a fundamental aspect of scene perception. However, not all pictures are scenes—only pictures construed as depicting a truncated view of a continuous world.

In our interaction with the visual world, most of the information we process comes from complex visual scenes. These scenes typically include multiple objects and complex backgrounds. Our environment extends all around us, but physiological constraints prevent us from ever seeing an entire scene at once. Head movements and eye movements provide us with successive views of a continuous world. Yet, in spite of the complexity inherent in scenes, and the spatial limitations on how much of the world we can see at one time, our understanding of the visual environment seems effortless. In this study we focused on the viewer's ability to remember how much of a scene was contained in a single view. We tested the hypothesis that when faced with a partial view of a continuous world, amodal continuation of scene layout plays a critical role in scene perception. Memory for spatial expanse was examined under conditions in which stimuli either were or were not understood to be scenes.

Intraub and her colleagues showed that when remembering a photograph of a scene, viewers tended to remember having seen a greater spatial expanse than was actually shown—they referred to this error as *boundary extension* (Intraub & Richardson, 1989; see also Intraub, Bender, & Mangels, 1992; Intraub, Gottesman, Willey, & Zuk, 1996; for demonstrations see Gottesman & Intraub, 1999).[1] They argued that to understand a partial view, the visual system must recognize that the scene continues beyond the current limits of that view. It is this mental extrapolation beyond the edges of the view that allows us to understand that a close-up portrait of a friend is a partial view of the whole person, rather than a severed head (Intraub & Richardson, 1989). This understanding would be fundamental to the interpretation of any occluded view, whether captured in a picture or seen in the real world. We have argued that a sketchy mental representation of scene layout and landmarks, similar to those proposed by Hochberg (1978, 1986) and Irwin (1991, 1993) in their discussion of the integration of successive views, is computed during scene perception.

Support for this position comes from research on transsaccadic memory (Irwin, 1991, 1993), change blindness (e.g., Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997), and aperture viewing (Hochberg, 1986), as well as research on picture perception and memory (see Intraub, 1997, for a general review). Examples from the latter two types of research include the observation that priming scene perception with a nondetailed sketch of a scene's layout improved the speed of distance judgments in photographs of scenes (Sanocki & Epstein, 1997) and evidence that presentation of multiple views of a location (e.g., a city intersection) results in the activation of a more general representation, in which missing views are filled in and later remembered as having been presented (e.g., Hock & Schmelzkopf, 1980).

In the case of boundary extension, evidence of layout extrapolation beyond the given view occurs as soon as 1 s following presentation (Intraub et al., 1996). Intraub and her colleagues (Intraub, 1997, 2002, in press; Intraub et al., 1996) argued that anticipatory representation beyond the edges of the view is adaptive because the world truly is continuous—wherever the eyes fixate, a saccade or head movement will indeed reveal more of the world. Anticipatory projections would (a) support comprehension of the scene that the picture only partially reveals, (b) help to

Carmela V. Gottesman and Helene Intraub, Department of Psychology, University of Delaware.

Experiments 1 and 2 were conducted in partial fulfillment of requirements for Carmela V. Gottesman's doctoral degree from the University of Delaware. Portions of this research were presented at the 38th Annual Meeting of the Psychonomic Society, Philadelphia, Pennsylvania (November 1997), and at the 39th Annual Meeting of the Psychonomic Society, Dallas, Texas (November 1998). This article was supported in part by National Institute of Mental Health Grant MH54688–01A1 awarded to the University of Delaware (Principal investigator: Helene Intraub).

We thank Samuel L. Gaertner for his very helpful comments during the preparation of Experiment 2.

Correspondence concerning this article should be addressed to Carmela V. Gottesman, who is now at the Department of Psychology, University of Oklahoma, 455 West Lindsey Street, Norman, Oklahoma 73019–2007, or to Helene Intraub, Department of Psychology, University of Delaware, Newark, Delaware 19716. E-mail: cvgottesman@ou.edu or intraub@udel.edu

[1] The boundary extension demonstrations described by Gottesman and Intraub (1999) can be viewed at http://faculty-staff.ou.edu/G/Carmela.Gottesman-1/web_page_exp.html

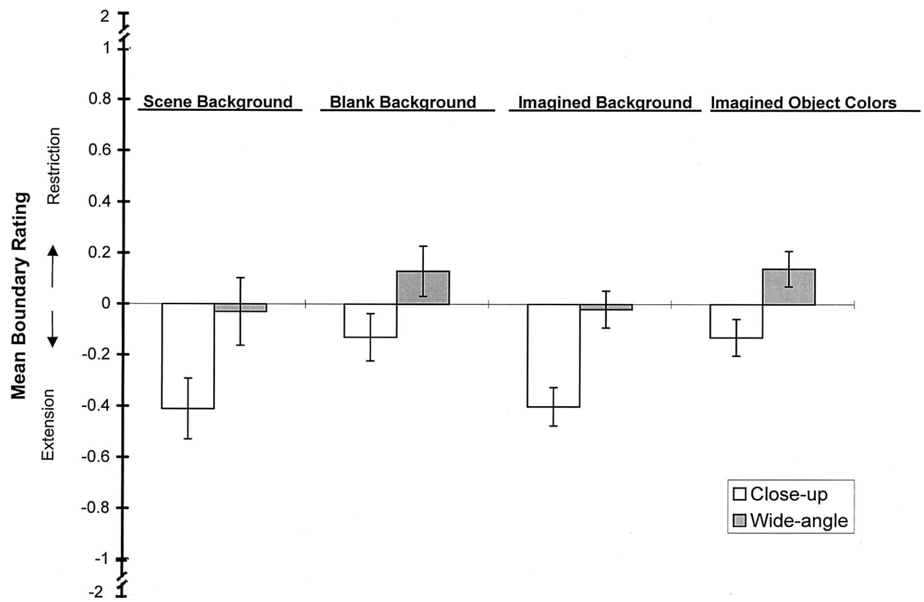

Figure 1. Mean boundary ratings for line drawings of objects with natural (scene) backgrounds, blank backgrounds, imagined backgrounds, or imagined object colors (on blank backgrounds) when presented as close-up or wide-angle views. Error bars show the .95 confidence intervals. Negative scores indicate viewers remember seeing more background (and a smaller object), and positive scores indicate they remember seeing less background (and a larger object). Data are from Tables 1 and 4 and from the results of Experiment 4 in Intraub, Gottesman, and Bills (1998).

integrate successive views by extrapolating layout, and (c) facilitate attention to unanticipated features that emerge in a new view. This extrapolation is part of the representation and results in boundary extension when memory is tested.

Many experiments have shown that tight close-ups of scenes yield the largest degree of boundary extension.[2] The degree of extrapolation diminishes as more wide-angle views are presented, with very wide-angle views yielding little or no extension (e.g., Intraub & Berkowits, 1996; Intraub et al., 1992). Intraub and her colleagues explain this by referring to the availability of salient information in such views; in a tight close-up, highly predictable spatial information is not shown in the picture, whereas in wider views, more of the expected surrounding space is actually presented. In the former case, the anticipated region is represented only through top-down extrapolation.

It is important to note that in immediate tests of memory, boundary restriction of close, standard, or wide-angle views does not occur. However, after delay (e.g., 2 days), boundary extension has been found to lessen in degree (Intraub et al., 1992; Intraub & Berkowits, 1996)—a somewhat surprising observation given that memory would not be expected to become more accurate over time. By analyzing the change in boundary extension over time for a subset of pictures presented with cohorts that were either slightly more close-up or slightly more wide-angle pictures, Intraub et al. (1992) found that the overall decrease in extension was attributable to a second process, referred to as *normalization,* in which views regress toward the average of the set. They proposed a two-component extension–normalization model to account for these observations. A similar two-component model has been proposed for representational momentum, another anticipatory phenomenon, in which the position of a moving object that stops is remembered as being farther along its path if tested immediately, and is then followed by position averaging that minimizes or eliminates the effect (Freyd & Johnson, 1987).

Intraub, Gottesman, and Bills (1998) directly tested the hypothesis that the extension component occurs only for pictures depicting a truncated view of a continuous visual world. Using line drawings, they showed that objects on blank backgrounds (i.e., no background depicted), and objects on natural backgrounds (e.g., grass, asphalt, carpeting) were processed differently. Figure 1 shows the contrasting patterns of results obtained when participants rated the remembered size of the same objects under these two conditions. As shown in the figure, in the scene-background condition, results mirrored those previously obtained in boundary-extension research (i.e., close-up objects were remembered as smaller, with more space in the background, and wide-angle ob-

[2] What is a close-up? We use the terms *close-up* and *wide-angle* in a relative way. Research on the effects of picture-view on boundary extension has used normative ratings to determine which views of a given scene are considered to be *close-up, standard,* and *wide-angle* (e.g., Intraub & Berkowits, 1996; Intraub et al., 1992). Although in many boundary extension experiments, including the present research, pictures contain a single main object or object cluster, in other research the pictures have included multiple objects spread across the scene. For example, you can have closer- and wider-angle views of one child in a three-legged race, and you can have closer- and wider-angle views of all 12 children in the race. When we have shown viewers a close-up of the full race, they do indeed experience boundary extension—showing more of cropped objects and more of the background. It may be the case that the position of the borders with respect to attended object(s) is a key determinant of the amount of boundary extension.

jects yielded no directional distortion). In contrast, in the blank-background condition, this did not occur. Consistent with the extension–normalization model (Intraub et al., 1992), with the extension component eliminated, all that remained was normalization. Close-up objects were remembered as smaller (with more surrounding space), and wide-angle objects were remembered as larger (with less surrounding space). Does the difference in the representation of these two stimulus types hinge on the background revealing part of a continuous world? In the scenes, visual information was presented right up to the edges, whereas in pictures with objects on blank backgrounds this, of course, was not the case, and perhaps this is what caused the difference.

To test this possibility, Intraub et al. (1998) presented only objects on blank backgrounds but provided different imagination instructions. In one condition they attempted to activate top-down scene knowledge by describing the natural background associated with each object and directing viewers to project an image of that background onto the picture (e.g., "the traffic cone is on a black asphalt road, with a shadow cast to the left"). Memory for the same pictures of line-drawn objects now yielded boundary extension; results were virtually identical to those in the scene condition (see Figure 1, *Imagined Background*). A control condition showed that imagination per se could not account for this result. When the objects' colors were described and the viewers were directed to mentally project them onto the line drawings, the pattern reverted to normalization (see Figure 1, *Imagined Object Colors*).

These results supported the premise that not all visual stimuli are processed in the same way. When the background is understood to be a truncated view of a continuous world (i.e., a *scene*), anticipatory processing outside the boundaries is evoked. This anticipatory spatial extrapolation, however, does not occur in the absence of a depicted (or imagined) spatial location in the picture space. It is interesting to note a similar distinction between scenes and nonscenes reported by Epstein and Kanwisher (1998) in a functional magnetic resonance imaging (fMRI) study in which brain activity was monitored during picture viewing. They reported the existence of a region of the parahippocampal cortex, which they called the *parahippocampal place area,* that responded strongly to passively viewed scenes such as empty rooms, furnished rooms, and landscapes but weakly to other stimuli such as single objects on blank backgrounds. In light of Intraub et al.'s (1998) imagery results, it is interesting to note that in a recent fMRI study, O'Craven and Kanwisher (2000) report that imagining locations also causes relatively high activation in the parahippocampal place area, as compared with imagining faces.

The differential processes found for scenes versus nonscenes in memory and in fMRI comparisons skirt a critical question: What is the principled difference between scenes and displays that are not scenes? What information needs to be in the display (or alternatively introduced to the display through imagination) that will evoke the activation of spatial expectations outside the view? One possibility is that in a scene, the truncation of depicted surfaces at the boundaries causes continuation similar to the well-known phenomenon of amodal completion. *Amodal completion* refers to the perception of occluded objects; the occluded objects are perceived to complete behind the occluding objects although the completion has no visual qualities such as luminance or color (Kanizsa, 1979; Michotte, Thines, & Crabbe, 1964/1991)—hence the term *amodal*. Nakayama and Shimojo (1992) argued that amodal completion is linked to our ability to understand the stability of surfaces in spite of the fact that different parts become visible as a viewer moves in front of an occluder. The completion has been shown to occur at an early stage in visual processing (He & Nakayama, 1992) and to be strongly connected to a perception of a 3-D layout (Yantis, 1995).

Completion as such cannot account for the phenomenon of boundary extension because viewers extend the boundaries in situations in which there are no incomplete objects (see Intraub et al., 1992). The extension in these cases is characterized by the continuation of the background, whether it is a solid surface (e.g., a fence or wall) or merely appears to be a surface (as in the case of the sky or a body of water). For this reason, boundary extension seems more related to a process complementary to amodal completion: surface spreading or amodal continuation. *Amodal continuation* refers to the continuation of a surface behind an occluder to an indefinite endpoint (Kellman & Shipley, 1991; Kellman, Yin, & Shipley, 1998; Shimojo & Nakayama, 1990; Yin, Kellman, & Shipley, 1997). This type of continuation may account for the extension of boundaries in the following way. If the picture depicts a continuous scene, then invariably the picture's boundaries truncate some surfaces. During scene perception viewers will tend to continue these surfaces, and later they will remember seeing more than they actually did. However, there may be some differences between spatial extrapolation in scene perception and in object perception because whereas objects in the world must have closure (even if the closure is hidden from view), scenes do not—they are continuous. Research on boundary extension has suggested that there are special processes associated with truncated views of scenes that are not elicited by pictures that depict objects without a scene context. Whereas the boundaries of a view tend to be extended in the mental representation of pictures of scenes (as well as in the representation of truncated views of real, 3-D scenes; Intraub, 2001; Intraub & Morelli, 2001; also see Intraub, 2002, in press), the same effect was not obtained for drawings of objects on blank backgrounds (Intraub et al., 1998).

In the present research, we proposed that to be treated as a scene by the visual system, the background in a display must be construed as being the visible portion of an occluded view (i.e., like looking at the world through a window). If the background is construed as representing part of a continuous world, mental extrapolation of the background will occur, resulting in boundary extension. If the background is not construed as representing part of a continuous world, then there will be no anticipatory projection outward. On the basis of the two-component extension–normalization model (Intraub et al., 1992), we predicted that if any error pattern is evident when boundary extension is eliminated, it should reflect normalization.

Experiment 1

The distinction between objects drawn on blank backgrounds and objects with scenic backgrounds is one that we have replicated four times with three sets of pictures (Gottesman, 1992; Intraub et al., 1998). Experiment 1 set out to test whether the same contrast would occur if instead of drawings on blank backgrounds, digitized photographs of objects on blank backgrounds were presented. With the aid of computer graphics, we deleted the backgrounds of scenes, leaving the main objects on a blank field. We expected that scenes would yield the typical pattern indicative of boundary extension (extension for close-ups and little or no extension for wide-angle views) but that objects on blank backgrounds would not. Instead, we predicted that if they showed any directional error, it would be normalization. A control condition was also created in which the pictures used in this experiment were traced to create line drawings comparable to those in our previous studies, to ensure that the effect would replicate with the new picture set.

Method

Participants. The participants were 251 students (127 women) from the University of Delaware who had volunteered to take part in the departmental participant pool.

Stimuli. There were three types of stimuli: photographs of objects in scenes, photographs of the same objects on blank backgrounds, and line drawings of those objects on blank backgrounds. There were 20 photographs of scenes in which a single object was presented on a simple natural background (e.g., a traffic cone on an asphalt road). There was a close-up view and a wide-angle view of each scene, totaling 40 photographs. The photographs of objects on blank backgrounds were created on the graphics system by using the AtVista Tips program and replacing the background with a homogeneous gray field. In another condition the gray field was replaced with a white field using the Adobe PhotoShop program. The line drawings of objects on blank backgrounds were created by tracing the main object in each photograph, leaving the background blank. The tracing was done on the computer by using Adobe PhotoShop and a SummaGraphics Sketch Tablet with a stylus. Therefore, the main object was the same size and in the same location in the picture space for each type of stimulus. Figure 2 shows one of the 20 scenes (the traffic cone) as a function of stimulus type and view.

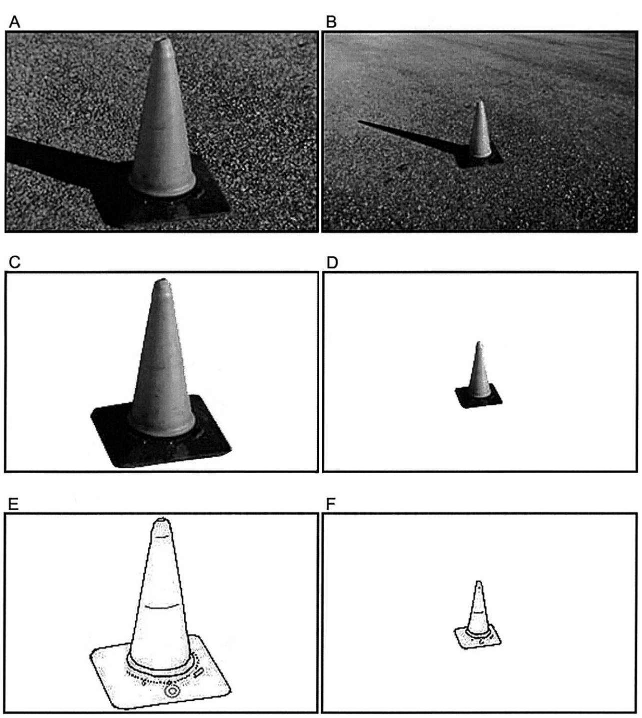

Figure 2. Sample of stimuli in Experiment 1. Close-up (left column) and wide-angle (right column) views of the traffic cone stimulus with a natural background (A and B), a blank background (C and D), and as a line-drawn object (E and F). All photographs were presented in color.

Apparatus. The conditions were run at two different times using two different graphics systems. The first system was comprised of an IBM-compatible computer (Intel 386/25 MHz) with a 4-Mb AtVista graphics board and a 13-in. (33-cm) Mitsubishi color monitor (Model FA3415ATK). Image resolution was 378 × 243 pixels × 16 bits of color. This produced a capability to display 65,536 different colors, which made up for the relatively low spatial resolution and produced a high-quality image. To help participants focus on the small screen and to provide a clear edge around the picture, we cut a rectangle (9.5 in. × 7.5 in. [24 cm × 19 cm]) out of the center of a black poster board. This board was attached to a wooden frame and placed directly in front of the monitor. In this way, the boundary of each picture was bordered by a black occluding field, as in previous boundary-extension studies. Participants sat in two rows of two chairs each. The approximate distance from the screen to the first and second row of seats was 72 in. (183 cm) and 93 in. (236 cm), respectively. The approximate visual angle was $8^\circ \times 6^\circ$ and $6^\circ \times 5^\circ$ for the first and second rows, respectively.

The second graphics system was comprised of a 200-MHz Intel Pentium computer with a 21-in. (53-cm) 445xi Nokia monitor. Sequences were presented using Corel Presentations 7. The resolution was 756 × 486 pixels × 16 bits of color. The image size was 14¾ in. × 9½ in. (37 cm × 24 cm) in the center of the screen. The rest of the screen was left blank, allowing a black area to surround each picture. Participants sat in three rows with three to four seats in each, centered in front of the screen in a dimly lit room. The distance between the screen and the first, second, and third rows was 81 in. (206 cm), 122 in. (310 cm), and 160 in. (406 cm), respectively. The approximate visual angles for participants sitting in the center of the front and back rows were $10^\circ \times 7^\circ$ and $5^\circ \times 3^\circ$, respectively.

Design and procedure. Two conditions were run on the Intel 386 system. Participants viewed either photographs of objects in scenes or photographs of the same objects on a gray homogeneous background (Ns = 41 and 40, respectively). The other three conditions were run using the Pentium system. In these conditions, participants viewed (a) photographs of the objects on a gray background, (b) photographs of the objects on a white background, or (c) line drawings of the objects on a blank background (N = 45, 47, and 78, respectively).

Prior to presentation, participants in all conditions were asked to try to remember the pictures in as much detail as possible, including their layout. They were specifically told to try to remember the size and location of everything in the picture space and to retain an exact copy of each picture in memory. In all the conditions, pictures were presented for 15 s each. Half the stimuli were presented in their wide-angle version and half in their close-up version, counterbalanced across participants. There was a difference in the presentation procedure for the conditions run on the two graphics systems. For the three conditions run on the Pentium system, items were presented for 15 s each with no interstimulus interval (ISI). In the case of the Intel 386 system, pictures were presented for 15 s each with a 3-s ISI during which the screen was gray. The pictures were presented in two sequences. The first sequence ended with the presentation of an unrelated filler picture, and there was a 20-s break between sequences during which a fixation point was presented. The short break was necessary because of the system's memory limitations.

In all conditions, the recognition test immediately followed presentation. Participants were told they would be shown the pictures again and were asked to use a 5-point scale (as in Intraub et al., 1998) to indicate whether each picture was the *same* (coded as 0), *slightly closer-up, object slightly bigger* (−1), *much closer-up, object much bigger* (−2), *slightly more wide-angle, object slightly smaller* (1), or *much more wide-angle, object much smaller* (2). The rating-scale terminology was illustrated using four views of a single scene that ranged from a tight close-up to a relatively wide-angle view. Participants were also given the option of saying that they did not remember seeing the test picture. After making a response, participants rated their confidence in each response as *sure*, *pretty sure*, or *not sure*.

All test pictures were presented for 15 s each with no ISI on the Pentium system and a 3-s ISI on the Intel 386 system. In all conditions, half of the stimuli were tested with target pictures; these were identical to half of the close-up and half of the wide-angle stimuli. The other half of the stimuli were tested with distractors; these were the opposite versions of the presented scenes. That is, half the distractors were close-up versions of wide-angle stimuli (designated as *CW*—close tested by wide), and half were wide-angle versions of close-up stimuli (designated as *WC*—wide tested by close).

Results and Discussion

Participants in all conditions were rather confident in their responses. Across conditions they rated their responses as *sure* 52%–61% of the time, as *pretty sure* 31%–40% of the time, and as *not sure* 6%–9% of the time.

Test item was identical to the stimulus (CC and WW conditions). We refer to a test item as a *target* when it is the same picture that was shown during presentation. The percentage of trials in which participants correctly recognized target pictures as being the same is shown in Table 1. The table shows that recognition accuracy was very similar across conditions. Participants frequently did not recognize that a picture was the same as before.

To determine whether boundary extension or normalization occurred, we obtained the mean boundary rating for CC targets and WW targets. The mean boundary ratings for photographs of objects in scenes, photographs of objects on blank backgrounds (collapsed over the three conditions), and line drawings of objects on blank backgrounds are shown in Figure 3. To determine whether each mean rating differed significantly from zero, we constructed the .95 confidence intervals for each mean, which are presented as error bars in the figure. If the boundary rating did not differ significantly from zero ("same"), then boundary extension did not occur. A significant departure from zero indicates a distortion in the remembered expanse of the picture. A negative rating indicates that the viewer remembered the picture as having shown more background area (object is remembered as having covered less of the picture space). A positive rating indicates that the viewer remembers the picture as having shown less background area (object is remembered as having covered more of the picture space).

Figure 3 shows that, as usual, when objects were presented in scenes, boundary extension occurred—close-ups were remembered as having shown more background, and wide-angle views yielded no directional bias. Surprisingly, in all three cases in which photographs of objects were shown on blank backgrounds, boundary extension was also obtained. Because the pattern of results was the same in all three conditions, we calculated the mean boundary ratings for close-up and wide-angle photographs of objects on blank backgrounds collapsed over the three conditions. As can be seen in Figure 3, the pattern of results for photographs of objects was the same whether the objects were presented in a scene or on a blank background.

The mean boundary ratings in the specific conditions were as follows: −0.22 ($SD = 0.33$) and 0.01 ($SD = 0.26$) for close-up and wide-angle objects on gray backgrounds run on the Intel 386 system, respectively; −0.14 ($SD = 0.30$) and −0.01 ($SD = 0.36$) for close-up and wide-angle objects on gray backgrounds run on the Pentium system, respectively; and −0.10 ($SD = 0.35$) and −0.01 ($SD = 0.33$) for close-up and wide-angle objects on white backgrounds, respectively. In all these conditions, .95 confidence intervals showed that the mean ratings for close-ups were significantly less than zero and the mean ratings for wide-angle views were not significantly different from zero, a pattern consistent with boundary extension. The pattern of results for all the photographs of objects on blank backgrounds indicates that boundary extension was obtained using both graphics systems and it was not affected by the background color.

Table 1
Percentage of "Same" Responses To Close-Up and Wide-Angle Targets for Photographs of Objects in Scenes, Cutout Objects on Blank Backgrounds (Gray or White), and Line Drawings of Objects on White Backgrounds (Experiment 1)

Condition	Close-up target *M*	Close-up target *SD*	Wide-angle target *M*	Wide-angle target *SD*
Photographs of objects in scenes	60	27	65	25
Cutout objects on blank backgrounds				
Gray background (Intel)	67	23	64	29
Gray background (Pentium)	61	26	68	23
White background	66	23	61	26
Drawings of objects on white backgrounds	63	25	69	23

In contrast to this, line drawings of the same objects on a blank background did not yield boundary extension. Instead, a significant normalization effect similar to that observed in prior research was evident. The close-up objects were remembered as having been smaller, and the wide-angle objects were remembered as having been larger (see Figure 3). The results from this stimulus set did not yield the remarkable symmetry we have seen for other line drawings of objects, but the pattern is clearly the same and differs markedly from that obtained in the other conditions.

Test item differed from the stimulus (CW and WC conditions). Participants were very good at detecting distractors and seldom mistook them as being the same as the stimulus. The mean percentage of "same" responses to distractor pictures varied between 2% and 6%.

In prior research, when boundary extension occurred for targets, we noted a tendency for there to be an asymmetry in the response to CW and WC distractors such that WC distractors were rated as being more similar to the original stimulus than were CW distractors. This would follow if the stimulus were remembered with extended boundaries. This asymmetry, however, depends on a priori selection of a wide-angle distractor that is close to the boundary extended memory.

To determine whether the magnitude of the ratings differed between the CW and WC conditions, we calculated the absolute value of the mean boundary ratings. The mean ratings for photographs of objects in scenes were 1.58 ($SD = 0.42$) and 1.74 ($SD = 0.30$) in the CW and WC conditions, respectively. The mean ratings for photographs of objects on gray backgrounds, using the Intel 386 system, were 1.65 ($SD = 0.30$) and 1.70 ($SD = 0.30$) in the CW and WC conditions, respectively. The mean ratings for photographs of objects on gray backgrounds, using the Pentium system, were 1.60 ($SD = 0.58$) and 1.63 ($SD = 0.63$) in the CW and WC conditions, respectively. The mean ratings for photographs of objects on white back-

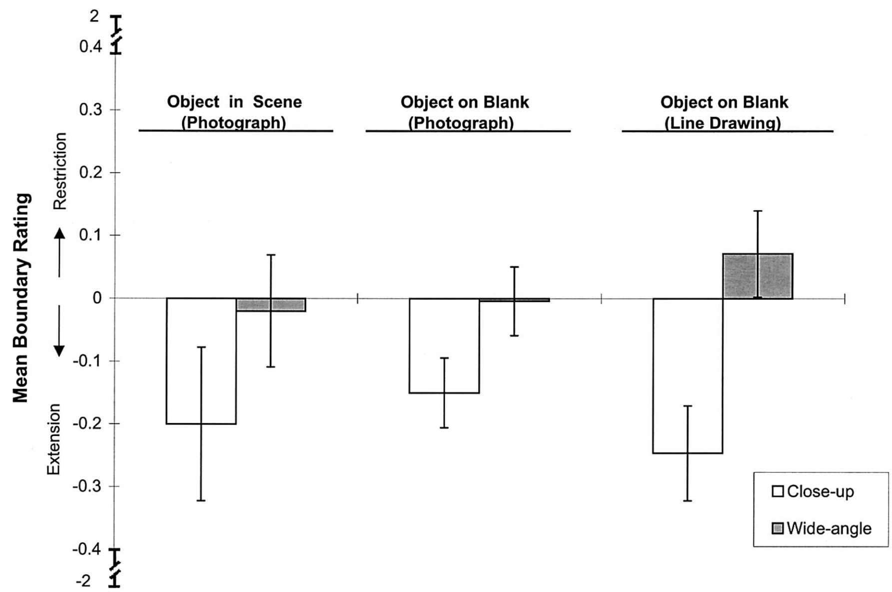

Figure 3. Mean boundary ratings for close-up and wide-angle views as a function of picture type: photographs of objects in scenes, photographs of objects on blank backgrounds (collapsing over the three replications), or line drawings of objects on blank backgrounds. Error bars show the .95 confidence intervals.

grounds were 1.65 ($SD = 0.54$) and 1.72 ($SD = 0.50$) in the CW and WC conditions, respectively. Each pair of means was subjected to a *t* test. In all the photograph conditions, the responses to distractors tended to be asymmetrical in the expected direction. For photographs of scenes, this tendency approached significance, $t(40) = 2.01$, $p = .052$, but not for the others ($t < 1.1$).

In prior research, conditions that yielded normalization rather than boundary extension for targets usually yielded a symmetrical response to the two distractor types. In the present case, however, the mean ratings for line drawings of objects on blank backgrounds were 1.54 ($SD = 0.48$) and 1.67 ($SD = 0.40$) in the CW and WC conditions, respectively. The *t* test showed that the line drawings condition yielded a significant asymmetry, $t(77) = 1.91$, $p < .01$. The asymmetrical aspect of the normalization is suggestive that something about the views in this set mitigates a bit against normalization, or it may simply be a result of random error.

In summary, the same set of objects on homogeneous blank backgrounds yielded boundary extension when photographs of the objects were presented and normalization when they were traced to make line drawings. This posed a serious problem for our theoretical framework, unless a principled explanation could be offered.

Experiment 2

In what way might a blank background be interpreted differently when an object is a color photograph as opposed to a line drawing? We hypothesized that in the case of line drawings, the blank background is perceived as depicting nothing—it is simply the paper on which the representation of an object was drawn. For this reason, the display is not understood to be a partial view of a continuous scene. On the other hand, when an object is photographed, it has to be photographed somewhere, and the blank background, although it contains no detail, is construed as being that surface—the display is understood as revealing a truncated view of a continuous world. This construal activates expectations about the continuation of the surface. If this interpretation is valid, then one can eliminate boundary extension and obtain normalization by biasing the observer's construal of the blank background. Specifically, if the blank background is not construed as representing a truncated view (as we claim occurs in the case of the line drawings), then the same stimuli should not support boundary extension, and a normalization pattern should occur instead. In a different setting, DeLoache (1995) reported that representational thinking in children could be biased by changing how a model (i.e., a small replica of a room) was presented: A model that could be played with was less likely to be understood as a representation of a larger room than a model presented under glass that could be viewed but could not support interactive play. In the present experiment, taking a related approach, we sought to find a way to eliminate the representational quality of the blank background.

To accomplish this, we printed and laminated the photographs of scenes used in Experiment 1. The main objects were physically cut out. These cutout objects were then presented manually on a white board in front of the viewers. Because the surrounding white area was clearly not a surface within the photograph (something we propose was not clear in Experiment 1), we assumed it would be interpreted in much the same way as the blank background in the object drawings. To ensure that the manual procedure itself would not eliminate boundary extension, we created a control condition in which the entire scene (object and natural background) was printed, laminated, and also presented manually on the white board. If our assumptions are correct, then the same cutouts that yielded boundary extension in the computer display should not yield boundary extension when presented on the white board. In accordance with the extension–normalization model, if a consistent memory error is obtained, it should reflect normalization. The cutout scenes, however, should yield boundary extension. If our assumptions about truncated space are incorrect and the results from Experiment 1 reflect differences in the way line-drawn objects and photographs of objects are processed, then the cutouts on blank fields should yield boundary extension, just as they did in the computer presentation in Experiment 1.

Method

Participants. The participants were 104 students (51 women) from the same population described in Experiment 1.

Stimuli. The stimuli were the same close-up and wide-angle views of scenes used in Experiment 1. Two copies of each scene were printed using Paint-Shop software on a Canon BJC-610 bubble jet printer. They were printed in color with a resolution of 360 × 360 dpi on glossy paper that was then glued to thin cards. One copy of each card was cut exactly to the edges of the photograph, making 3½-in. × 2 7/16-in. (9 cm × 6 cm) cards showing the objects in a scene context. The other printed copy was used to make the cutout objects. The main object from each scene was cut out using scissors, making puzzle pieces (see Figure 4).

Both types of pictures were laminated, and the laminate covered only the picture itself (there were no lamination edges). Thus, the size of the object in any given scene was exactly the same as the size of the corresponding cutout object.

Apparatus. The pictures were presented on a 30-in. × 20-in. (76 cm × 51 cm) white foam board. On the board a 3½-in. × 2 7/16-in. (9 cm × 6 cm) rectangle was drawn in black marker. In the middle of this rectangle there was a piece of transparent two-sided tape to which the stimuli were attached during presentation. The participants sat in two chairs about 48 in. (122 cm) from the board on which the pictures were presented. The visual angle of the black rectangle on the board was about 4° × 3°. A stopwatch was used to time the presentation and test times.

Design and procedure. Participants were randomly assigned to one of two conditions: the photograph-scene condition ($N = 52$) or the cutout-object condition ($N = 52$). They were tested either individually or in pairs. Participants were told that they would see a series of pictures on the white board and they were to try to remember them in as much detail as possible (e.g., they should try to remember color, shading texture, etc.). The experimenter held up an example of the type of pictures that the participant would see: either a photograph of an object set in a natural background or a cutout of the object.

Half the pictures presented to each group were close-up views and half were wide-angle views, counterbalanced across participants. During the presentation the experimenter placed the pictures within the outline rectangle on the board. The photographs (objects and natural background) fit inside the black rectangle. In the cutout-object condition, the experimenter held a printed version of each photograph out of the participants' view. By consulting the photograph, the experimenter placed each cutout object in the black rectangle such that the object was in the same location and orientation within the rectangle as it was in the scene. Each picture was left on the board for 15 s, and it took about 5 s for each picture to be replaced by the next.

After the presentation, participants viewed the same pictures again on the board. Using the same rating scale as in Experiment 1, they reported whether the test picture was the *same, slightly more close up—object slightly bigger, much more close up—object much bigger, slightly more wide-angle—object is slightly smaller, or much more wide-angle—object much smaller.*

Results and Discussion

As in the previous experiment, participants tended to be confident. They rated 56% of their responses in both conditions as *sure*, 36%–37% as *pretty sure*, and 7%–8% as *not sure*. The percentage of "same" responses for distractors varied between 2% and 4%.

Test item was identical to the stimulus (CC and WW conditions). The percentage of scene targets correctly recognized was 57% ($SD = 27$) for close-ups and 71% ($SD = 26$) for wide-angle views. The percentage of cutout targets correctly recognized was 64% ($SD = 27$) for close-ups and 68% ($SD = 27$) for wide-angle views.

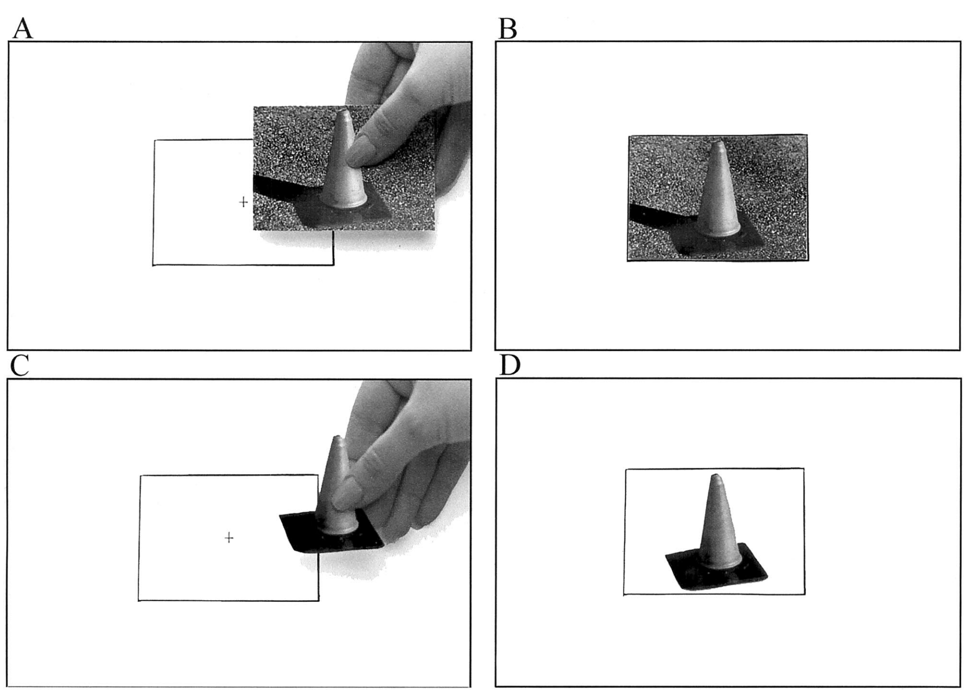

Figure 4. Example of objects with natural backgrounds (A and B) and cutout objects (C and D) being placed on the blank field in Experiments 2 and 3.

The mean boundary ratings for photographs of scenes and cutout objects is shown in Figure 5 (the error bars indicate the .95 confidence intervals). The figure shows that the scenes yielded boundary extension but that cutout objects yielded normalization.

Test item differed from the stimulus (CW and WC conditions). As in Experiment 1, the absolute values of the mean boundary rating to close-up distractors and to wide-angle distractors were compared to determine whether or not they were symmetrical. The mean ratings for the scene stimuli were 1.62 ($SD = 0.32$) and 1.73 ($SD = 0.27$) in the CW and WC conditions, respectively. The ratings reflected the asymmetry generally associated with boundary extension (i.e., the mean rating for close-up distractors was larger in absolute value than the mean for wide-angle distractors, $t(51) = 2.03$, $p < .05$. The mean ratings for the cutout objects were 1.68 ($SD = 0.27$) and 1.68 ($SD = 0.44$) in the CW and WC conditions, respectively. These means reflect a perfect symmetry in responses to close-up and wide-angle distractors ($t < 1$).

Experiment 3

The same photographs of objects on blank backgrounds that repeatedly yielded boundary extension in Experiment 1 yielded normalization in Experiment 2. Biasing the viewer's construal of the blank surface reversed the effect as predicted. However, one potential confounding factor needed to be addressed before concluding that background construal determines whether or not extrapolation will be initiated. In Experiment 2, to provide all participants with an equally good memory test—one that would allow the best performance possible—test items were always the same as the stimuli. Scenes were tested with scenes, and cutout objects were tested with cutout objects. However, although this minimized one problem, it raised another. The test items were different in the two conditions. Maybe testing with puzzle pieces held between the experimenter's fingers would result in normalization no matter what kind of stimulus preceded it. To test this, we presented participants with the scenes (see Figures 4A and 4B) but tested them with the cutout objects (see Figures 4C and 4D). If the cutout objects provide a good test of memory for remembered object size, then testing scene memory by showing the objects alone should still yield a pattern consistent with boundary extension. If the normalization pattern was an artifact of testing with cutout objects, then normalization should occur even though scenes were presented.

Method

Participants. The participants were 53 students (25 women) from the same population described in Experiment 1.

Stimuli and procedure. The stimuli were the same as in the scene condition of Experiment 2. The test items (targets and distractors) were the same as in the cutout-object condition of Experiment 2. The procedure was the same as in Experiment 2 except that memory for the objects in the scenes was tested with cutouts of those objects. Using the same instructions as before, we presented participants with the scenes and asked them to remember them in as much detail as possible. Immediately after the presentation, they were presented with the cutout objects. Participants were asked to compare each object with the object they remembered seeing in the scene. They rated the test object on the same 5-point scale used in Experiment 1 and then rated their confidence as in the previous experiment.

Results and Discussion

Participants were again rather confident about their responses, rating 54.3% of the responses as *sure,* 36.9% of the responses as *pretty sure,* and 6.4% of the responses as *not sure.*

Test item was identical to the stimulus (CC and WW conditions). The mean percentage of "same" responses to targets was 39% ($SD = 26$) for close-up targets and 70% ($SD = 22$) for wide-angle

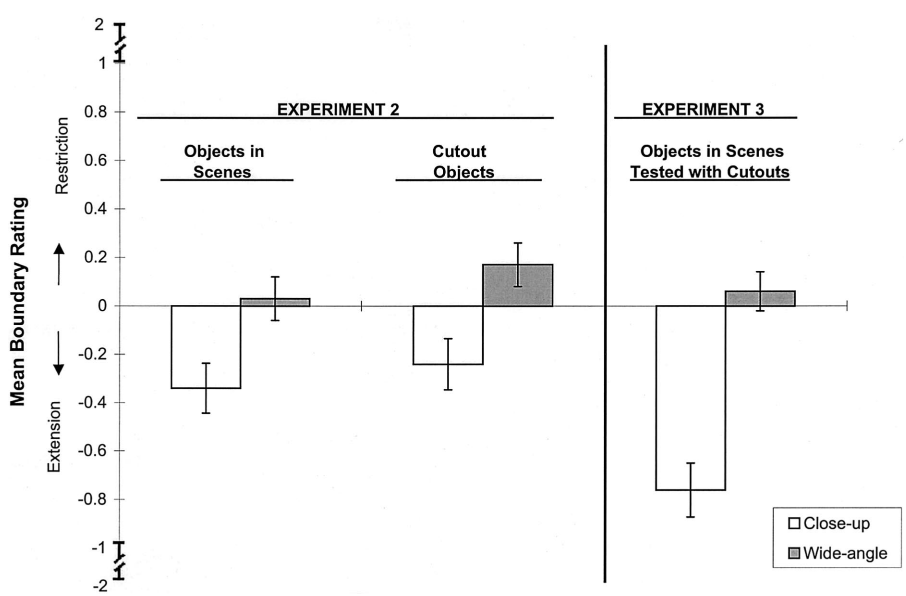

Figure 5. Mean boundary ratings for close-up and wide-angle pictures as a function of picture type: scenes versus cutout objects. In Experiment 2 viewers saw the same type of stimulus during the presentation and the test. In Experiment 3 viewers saw the scenes during the presentation and the cutout objects during the test. Error bars show the .95 confidence intervals.

targets. The mean boundary ratings showed that when tested with cutout objects, memory for the scenes yielded the same results as before. The mean boundary ratings given when viewing close-up and wide-angle cutout objects after having viewed the objects within a scene context are shown in Figure 5 (error bars show the .95 confidence interval). Boundary extension was clearly evident. The figure shows that the mean rating for close-ups was significantly smaller than 0, and the mean boundary score for wide-angle pictures did not differ significantly from 0, showing no directional bias.

Test item differed from the stimulus (CW and WC conditions). For the distractors, the mean percentage of "same" responses was 9% ($SD = 14$) for the wide-angle distractors and 2% ($SD = 7$) for the close-up distractors. Responses to distractors showed the typical asymmetry pattern obtained when there is boundary extension. The absolute values of mean ratings were 1.46 ($SD = 0.43$) and 1.77 ($SD = 0.26$) in the CW and WC conditions, respectively. A t test showed that the asymmetry was significant, $t(52) = 4.42$, $p <$ .001. The wide-angle distractors were rated as looking significantly more similar to the original stimulus than were the close-up distractors.

Clearly, memory for the scenes was the same regardless of whether it was tested by showing the scenes again or by showing the object alone. This shows that it is the construal during perception and not the test type that influences memory and results in either boundary extension or normalization.

General Discussion

When is a picture a scene? The results of these experiments demonstrate differential spatial memory for pictures of objects, depending on how their blank backgrounds are construed by the viewer. We propose that when the background depicts part of a continuous surface or when it can be construed as such, it will activate a mental representation of scene layout that extends beyond the edges of the current view. This activation becomes incorporated in memory and results in viewers remembering having seen a greater expanse of the scene than was shown (boundary extension). According to this view, amodal continuation of surfaces plays a critical role in scene comprehension and memory. We use the term *amodal* because the viewer does not actually see the continuation. However, we argue that a truncated view of a continuous surface elicits spatial extrapolation. In Experiment 1 we found that in contrast to line drawings of objects, photographs of objects on blank backgrounds activated spatial expectancies beyond the edges of a picture. We hypothesized that the reason viewers interpreted the blank background differently in these two conditions is that for the photographs of objects, the homogenous background was interpreted as the surface on which the object was placed when it was photographed. This interpretation is reasonable because the photographed objects were indeed embedded in scenes when they were photographed. It was only the trickery of computer editing that created the photographs with no visual detail in the background.

The results of Experiment 2 supported this explanation. How the blank background was construed determined whether boundary extension or normalization occurred in memory for photographs of objects. When the objects were physically cut out and placed on a blank rectangular field in front of the viewer, boundary extension was eliminated and a clear normalization pattern emerged. The pattern of results was identical to that obtained for line drawings of objects on blank backgrounds (Experiment 1 and Intraub et al., 1998). In this case, it was evident to the observers that the background did not represent a surface that the object was resting on when it was photographed. Spatial extrapolation did not occur. Experiment 3 showed that this outcome was not the result of testing with cutout objects per se. When viewers were presented with the scene versions of the same objects and were tested with the cutout objects, boundary extension again occurred.

We interpret these results as showing that the key element in understanding and remembering scenes is amodal continuation of surfaces truncated by the boundaries. In perceiving a partial view of a continuous world, amodal perception plays an important role. Both photographs and drawings of objects on natural backgrounds (e.g., a traffic cone on an asphalt road) yield boundary extension (Intraub et al., 1998). But clearly there are cases in which the same effect can be found for photographs of objects on blank backgrounds when those backgrounds are construed as continuous surfaces. This suggests that background details are not necessary to evoke extrapolation of the background. In fact, in another experiment, Gottesman (1998) found that extrapolation occurred even when the background was cut up and jumbled (similar to Biederman, Glass, & Stacy, 1973). Although there was no longer a well-organized scene, the background seemed to be interpreted as a surface resembling a patchwork quilt. Other research has shown that a simple texture gradient behind a nondescript volumetric shape yields the same extension as a meaningful detailed scene (Gottesman, 1999).

Apparently, what is required for amodal continuation to occur is the perception of a continuous background that is truncated by the edges of the picture. Converging evidence has been obtained in new research in which we set out to determine whether spatial extrapolation would occur in the face of any surrounding boundary or just the boundary of the view. Gottesman and Intraub (2001) showed viewers photographs including two objects that were placed on top of one another on a surface, such as a plate on a tray on a table. The view of the tabletop was truncated by the edges of the picture. They found that viewers extended the boundaries of the truncated background surface (the tabletop, in this example) but did not extend the boundaries of the intermediate object's surface (the tray, in this example): That is, the area of the tray was not increased with respect to the plate. Thus the presence of backgrounds that are likely to continue beyond the edges of the depicted view is what distinguishes scenes from nonscenes.

Alternative Explanation

An alternative explanation of boundary extension is that it is primarily a distance effect, in which observers remember objects as being farther away in the picture, followed by a filling in of information around the edges (Hubbard, 1995, 1996; Previc, 1998). In their initial report, Intraub and Richardson (1989) pointed out that indeed boundary extension might reflect either changes in remembered distance ("I [or the camera] was farther away from the objects") or extrapolation beyond the edges of the view ("I saw [or the camera captured] a greater expanse of the scene"). In a picture, those two factors are, in effect, confounded. A picture that shows more of the periphery usually is one that is taken from a greater distance. In the context of the present experiment, this alternative view would suggest that scenic backgrounds would trigger the distance error but blank backgrounds would not.

Recently, Intraub (2002) contrasted these two perspectives, providing two arguments against the distance hypothesis. She argued that the adaptive value of anticipating layout just outside the current view is readily apparent—in any view of the world, there is always more (just beyond the edges) that can be brought into view by a saccade or a head movement. There is value to anticipating this invariant aspect of the world during integration of successive views. In contrast, the adaptive value of remembering a view as being farther away is not readily apparent. People approach, step away from, and walk around objects all the time. What advantage would accrue from consistently remembering objects as being farther away immediately after viewing them? Such an error, she argued, would likely be maladaptive.

The second argument is based on recent research on spatial memory for 3-D scenes (in which distance is not confounded with the expansiveness of the view; Intraub, 2001; Intraub & Morelli, 2001; also see Intraub, 2002, in press). In these experiments, six to seven real scenes (three to five objects in each on a natural background) were covered by yards of black cloth in which there was a rectangular aperture that revealed part of the scene. For example, in the dog scene, a dog's dish, leash, and rawhide bone were arranged on a tile floor, and the aperture allowed a 2-ft $\times$ 2-ft (1.2-m $\times$ 1.2-m) view of the scene (truncating the view of the floor). After studying the scenes, the participant waited in another room while the occluding cloth was removed. About 5 min later, the participants returned and reconstructed the borders of the aperture. Their reconstruction yielded boundary extension. For example, in one experiment (Intraub, 2001), 20 participants viewed six different occluded scenes for 30 s each. In reconstructing the aperture, they included, on average, 53% more of the surrounding background than had been shown. Significant amounts of boundary extension occurred for each of the six scenes, with mean increases in area ranging from 28% to 94% across the scenes.

It is important to note that viewers did not step back from the scenes, indicating a remembered displacement in distance, but stayed in the same location and marked off an area that included a surrounding, previously unseen, region of the background. In another condition, the same scenes were explored haptically by blindfolded participants. Results also yielded boundary extension. In terms of the present discussion, it is important to note that in these cases, the participants had very strong cues as to their distance from the explored region (it was within arms reach!)—yet boundary extension occurred. If mental displacement away from the view was the underlying cause of boundary extension, then boundary extension should not have occurred in the haptic condition. The results of the 3-D studies are consistent with our proposal that boundary extension reflects the mental extrapolation of a truncated view of a continuous scene, not a displacement in depth.

Amodal Perception

Boundary extension appears to be a continuation of background properties (colors, textures, and patterns) that is not driven by a completion of object contours (as in amodal completion). Similar findings can be seen in the amodal perception literature. In their research on shapes, Yin, Kellman, and Shipley (2000) have shown that fragmented surfaces are integrated on the basis of surface properties (color) as well as shape contours (object edges). Moreover, Yin et al. (1997) reported evidence that surface color gradients sometimes lead viewers to perceive surfaces as continuing into areas where amodal perception would be unlikely to occur on the basis of contour information alone. When two surfaces are interpreted as belonging together on the basis of color gradients, people may continue the surfaces in order to unite them. This evidence suggests that amodal continuation can occur without reliance on the continuation of the contours of surfaces. This is similar to boundary extension because, as Experiment 1 shows, background continuation can occur even when no object contours are truncated by the edges of the picture.

The amodal continuation evident in boundary extension may be elicited in part by bottom-up markers (e.g., similar to T-junctions in amodal completion) and in part by internalized constraints about the likely structure of real-world scenes (in that imagined scene backgrounds also yield boundary extension; Intraub et al., 1998). The experiments described here suggest that in ambiguous situations (like a blank background) the default is to interpret the object's background as representing a location unless something suggests otherwise (e.g., objects that are drawn on paper, or cutout photographs of objects placed on a background that is not part of the picture). If nothing countermands the default, a blank background will elicit amodal continuation (as occurred repeatedly in Experiment 1 when photographs of objects on blank backgrounds were presented). This shows that spatial extrapolation does not require a detailed background, just the suggestion of a truncated view. The representation that emerges as a result of both perceiving a view and extrapolating beyond its boundaries could provide a good understanding of the scene without necessarily including a lot of detail from one glimpse to the next, thus allowing for both good comprehension on the one hand and change blindness on the other (Grimes, 1996; McConkie & Currie, 1996; O'Regan, 1992; Rensink, 2000; Rensink et al., 1997, 2000).

In conclusion, the present research shows that extrapolation of spatial layout in the mental representation of scenes is influenced by top-down construal of space. A blank background behind an object will tend to be remembered as more expansive if it is construed as representing a truncated view of a continuous environment within which the object is situated. This will not occur, however, if the blank background is not understood to be a truncated view (i.e., if it is merely understood to be the white board on which the pictorial representation of an object was placed). In this case, the display no longer depicts a scene and no longer activates anticipatory spatial layout. This same dichotomy was reported in previous research contrasting memory for line-drawn scenes versus line-drawn objects and memory for line-drawn objects under scene imagination conditions versus color imagination conditions (Intraub et al., 1998). Boundary extension occurred not only when the information in the picture indicated that it depicted a partial view but also when this information was inferred or imagined. Therefore, it is evident that anticipatory spatial extrapolation in memory for scenes is clearly not driven solely by bottom-up information (e.g., T-junctions created when the border truncates the background). Rather, anticipatory processes work interactively with external stimulation and internal expectations to help in perceiving a continuous complex world that can only be sensed piecemeal.

References

Biederman, I., Glass, A. L., & Stacy, E. W. (1973). Searching for objects in real world scenes. *Journal of Experimental Psychology, 97,* 22–27.

DeLoache, J. S. (1995). Early understanding and use of symbols: The model model. *Current Directions in Psychological Science, 4,* 109–113.

Epstein, R., & Kanwisher, N. (1998, April 9). A cortical representation of the local visual environment. *Nature, 392,* 598–601.

Freyd, J. J., & Johnson, J. Q. (1987). Probing the time course of representational momentum. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 259–268.

Gottesman, C. V. (1992). *Distorted memory for picture boundaries in photographs and drawings.* Unpublished senior thesis, University of Haifa, Haifa, Israel.

Gottesman, C. V. (1998). The role of the perceptual schema in the representation of visual scenes (Doctoral dissertation, University of Delaware, 1998). *Dissertation Abstracts International, 59,* 2446.

Gottesman, C. V. (1999, November). *Boundary extension for abstract scenes.* Poster presented at the 40th Annual Meeting of the Psychonomic Society, Los Angeles.

Gottesman, C. V., & Intraub, H. (1999). Wide-angle memories of close-up scenes: A demonstration of boundary extension. *Behavior Research Methods, Instruments & Computers, 31,* 86–93.

Gottesman, C. V., & Intraub, H. (2001). *Memory for inter-object relations: Does boundary extension occur within a scene?* Manuscript submitted for publication.

Grimes, J. (1996). On the failure to detect changes in scenes across saccades. In K. Akins (Ed.), *Perception* (Vancouver Studies in Cognitive Science, Vol. 5, pp. 89–110). New York: Oxford University Press.

He, Z. J., & Nakayama, K. (1992, September 17). Surfaces versus features in visual search. *Nature, 359,* 231–233.

Hochberg, J. (1978). *Perception* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Hochberg, J. (1986). Representation of motion and space in video and cinematic displays. In K. J. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance* (Vol. 1, chap. 22, 1–64). New York: Wiley.

Hock, H. S., & Schmelzkopf, K. R. (1980). The abstraction of schematic representations from photographs of real-world scenes. *Memory & Cognition, 8,* 543–554.

Hubbard, T. L. (1995). Environmental invariants in the representation of motion: Implied dynamics and representational momentum, gravity, friction, and centripetal force. *Psychonomic Bulletin & Review, 2,* 322–338.

Hubbard, T. L. (1996). Displacement in depth: Representational momentum and boundary extension. *Psychological Research, 59,* 33–47.

Intraub, H. (1997). The representation of visual scenes. *Trends in Cognitive Science, 1,* 217–222.

Intraub, H. (2001). *Anticipatory spatial representation in a blind and deaf observer.* Manuscript submitted for publication.

Intraub, H. (2002). Anticipatory spatial representation of natural scenes: Momentum without movement? *Visual Cognition, 9,* 93–119.

Intraub, H. (in press). Internalized constraints in the representation of spatial layout. *Behavioural & Brain Sciences*.

Intraub, H., Bender, R. S., & Mangels, J. A. (1992). Looking at pictures but remembering scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 180–191.

Intraub, H., & Berkowits, D. (1996). Beyond the edges of a picture. *American Journal of Psychology, 109,* 581–598.

Intraub, H., Gottesman, C. V., & Bills, A. (1998). Effect of perceiving and imagining scenes on memory for pictures. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 186–201.

Intraub, H., Gottesman, C. V., Willey E. V., & Zuk I. J. (1996). Boundary extension for briefly glimpsed photographs: Do common perceptual processes result in unexpected memory distortions? *Journal of Memory and Language, 35,* 118–134.

Intraub, H., & Morelli, F. (2001). *Boundary extension is memory for scenes following visual or haptic exploration.* Manuscript in preparation.

Intraub, H., & Richardson, M. (1989). Wide-angle memories of close-up scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 179–187.

Irwin, D. E. (1991). Information integration across saccadic eye movements. *Cognitive Psychology, 23,* 420–456.

Irwin, D. E. (1993). Perceiving an integrated visual world. In D. E. Meyer & S. Kornblum (Eds.), *Attention and performance XIV: Synergies in experimental psychology, artificial intelligence, and cognitive neuroscience* (pp. 121–142). Cambridge, MA: MIT Press.

Kanizsa, G. (1979). *Organization in vision*. New York: Praeger.

Kellman, P. J., & Shipley, T. F. (1991). A theory of visual interpolation in object perception. *Cognitive Psychology, 23,* 141–221.

Kellman, P. J., Yin, C., & Shipley, T. F. (1998). A common mechanism for illusory and occluded object completion. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 859–869.

McConkie, G. W., & Currie, C. B. (1996). Visual stability across saccades while viewing complex pictures. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 563–581.

Michotte, A., Thines, G., & Crabbe, G. (1991). Amodal completion. In A. Michotte, G. Thines, A. Costall, & G. Butterworth (Eds.), *Michotte's experimental phenomenology of perception* (pp. 140–167). Hillsdale, NJ: Erlbaum. (Original work published 1964)

Nakayama, K., & Shimojo, S. (1992, September 4). Experiencing and perceiving visual surfaces. *Science, 257,* 1357–1363.

O'Craven, K. M., & Kanwisher, N. (2000). Mental imagery of faces and places activates corresponding stimulus-specific brain regions. *Journal of Cognitive Neuroscience, 12,* 1013–1023.

O'Regan, J. K. (1992). Solving the "real" mysteries of visual perception: The world as an outside memory. *Canadian Journal of Psychology, 46,* 461–488.

Previc, F. H. (1998). The neuropsychology of 3-D space. *Psychological Bulletin, 124,* 123–164.

Rensink, R. A. (2000) The dynamic representation of scenes. *Visual Cognition, 7,* 17–42.

Rensink, R. A., O'Regan, J. K., & Clark, J. J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science, 8,* 368–373.

Rensink, R. A., O'Regan, J. K., & Clark, J. J. (2000). On the failure to detect changes in scenes across brief interruptions. *Visual Cognition, 7,* 127–145.

Sanocki, T., & Epstein, W. (1997). Priming spatial layout of scenes. *Psychological Science, 8,* 374–378.

Shimojo, S., & Nakayama K. (1990). Amodal representation of occluded surfaces: Role of invisible stimuli in apparent motion correspondence. *Perception, 19,* 285–299.

Simons, D. J., & Levin, D. T. (1997). Change blindness. *Trends in Cognitive Science, 1,* 261–267.

Yantis, S. (1995). Perceived continuity of occluded visual objects. *Psychological Science, 6,* 182–186.

Yin, C., Kellman, P. J., & Shipley, T. F. (1997). Surface completion complements boundary interpolation in the visual integration of partly occluded objects. *Perception, 26,* 1459–1479.

Yin, C., Kellman, P. J., & Shipley, T. F. (2000). Surface integration influences depth discrimination. *Vision Research, 40,* 1969–1978.

Received August 9, 2000
Revision received April 25, 2001
Accepted September 4, 2001 ■