The Role of Eye Movements in Perceptual Processes
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CONTEXTUAL FACTORS IN SCENE PERCEPTION

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1. Introduction

A picture depicts only a part of a real-world scene. The artist determines how much of the scene will be shown within the picture's boundaries. Comprehension of the picture, however, cannot be limited to the depicted information alone, but must take into account the context that "exists" just outside the picture's boundaries. For example, when we study the portrait of a friend, we see only a head and neck, yet we don't gasp at the apparent decapitation of a comrade. In perceiving the portrait, we perceive that the rest of the friend and the rest of the scene continue beyond the edges of the picture. It is as if we were viewing the person through a window. In a sense, the structure of the world just outside the boundaries of a picture may be as tangible to the perceiver as information that exists just outside a window frame.

A bounded picture in many ways may be considered analogous to the "visual picture" captured by a single eye fixation during visual scanning. An eye fixation provides the viewer with a detailed glimpse of only a part of the available scene. Visual acuity drops off rapidly for information falling outside the fovea on each fixation. Although, unlike the case of the picture, the information in the periphery is not excluded (or occluded as in the case of the window), it is degraded. This means that only a part of the visual field can be perceived clearly at any given time. This characteristic of visual processing is the basis of a classic question in the field of perception. How can successive, spatially constrained, discrete eye fixations yield perception of a stable, continuous, visual world. The level at which these successive fixations are integrated with one another, thus yielding the perception of a continuous visual world, remains in question.

It has been acknowledged that retinotopic visual persistence (a retinotopic icon) is not a likely medium for the integration of eye fixations (e.g., Haber, 1983; Neisser, 1967). Because the viewer makes numerous head and eye movements during visual processing, information from each successive fixation would be likely to overlap the same retinal area, resulting in more interference (through masking) than integration across saccades. Spatiotopic visual persistence, however, would eliminate this problem. It has been suggested that integration of successive iconic representations based upon spatial rather then retinal coordinates might provide the viewer with the perception of a stable, continuous visual world.

The classic research associated with this hypothesis was conducted by Davidson, Fox, and Dick (1973). They presented subjects with a display of letters during one fixation and then had them shift fixation slightly to a new location. During this new fixation a visual mask was presented at one of the letter positions. They reported that the letter that had shared *retinal* coordinates with the mask, was masked but the letter that had shared its *spatial* coordinates was perceptually integrated with the mask. This intriguing observation suggested that the stable visual world we perceive might be the result of spatial persistence and integration in a short-term visual memory. However, there have been some criticisms of this research on methodological grounds coupled with a failure to demonstrate spatiotopic persistence and integration when methodological changes were introduced (e.g., Irwin, Yantis, & Jonides 1983; Irwin, Brown, & Sun, 1988).

The possibility that successively glimpsed visual areas persist and are pieced together in an integrative memory is still open. However, another possibility is that visual persistence is not the primary medium that underlies visual comprehension of successive fixations. It is possible that each fixation is perceived in relation to an abstract mental representation of the environment that serves as a mental map (e.g., Hochberg, 1978, 1986; Irwin, Brown, & Sun, 1988). It is this mental map that provides the visual context within which each successively viewed area is "placed" and understood.

Bearing this in mind, consider once again the analogy between a picture and a single eye fixation on a scene. If a mental schema that represents the area outside the boundaries of a picture plays an integral role in picture perception, this same representation may play a role in the perception of successive eye fixations during visual scanning. The schema would provide a storage system for the incorporation of currently fixated information with previously fixated information, and would provide visual/spatial expectations about the information that is likely to be extracted in subsequent fixations. The same mental map that allows us to understand a close-up of a friend's face may underlie our ability to rapidly understand successive views.

How to study the nature and, in fact, the existence of such a schema is a difficult question. In this chapter I will provide a description of a picture memory phenomenon called "boundary extension" (Intraub and Richardson, 1989), that may provide a means for studying the perceptual schema used in picture perception. The basic observation is that when recollecting a picture, observers tend to remember having seen information that was not present in the picture itself, but that is likely to have existed just outside the picture's boundaries. Using recall and recognition tests, my students and I have been attempting to determine if the "additional" information is derived from the activation of a mental schema during picture perception. Recent research designed to test this hypothesis will be reported. Finally, the implications that this research and other picture processing research have for our understanding of the integration of successive fixations during visual scanning will be addressed.

I will begin with a review of Hochberg's (1978, 1986) analysis of the role of mental schemata or maps in perception, as this will provide the basis for one of the major hypotheses tested in the boundary extension experiments.

2. The Perceptual Schema

Hochberg (1978, 1986) has been a major proponent of the view that an abstract, schematic, mental structure plays a fundamental role in perception. Hochberg has argued convincingly that such a structure must underlie the comprehension of successive glimpses, basing his case upon an analysis of the viewer's ability to understand motion picture and video displays. Such displays include rapid shifts of the camera's view - shifts that the viewer could never make via his or her own locomotion. Hochberg argues that the ease with which an observer comprehends these shifts in viewpoint raises serious problems for the theory of direct perception (e.g., Gibson, 1950). Furthermore, he proposes that the capabilities suggest the use of mental schemata of space and events within which successive views are analyzed and understood. He demonstrates the likelihood of such a mental structure through an analysis of film editing techniques and descriptions of laboratory experiments. One such experiment is particularly relevant to the discussion here.

Hochberg (1978, 1986) describes research in which a movie was made which showed a circular aperture through which successive nonoverlapping views of an outline cross could be seen. Each view was a close-up of a part of the cross, so that only two perpendicular lines were visible at a time. The views were changed at a rate of 2-3 per second. When viewers were unaware that the display was intended to depict an outline cross moving behind an aperture, they often perceived it as hands moving around the circular face of a clock. However, when the viewer was told about the cross behind the aperture, or was provided with a long shot of the cross followed by a medium shot and close-up, thus establishing that the cross was behind the aperture, the perception changed. Although the aperture never allowed the whole outline cross to be seen at one time, the viewers "perceived" its existence outside the boundaries of the circle. Their perception of a cross moving behind a circular opening was accurate enough to allow them to recognize when one of the arms of the cross had been skipped.

The point of this demonstration is that the viewer's visual perception depended not only on the stimulus input, but upon a mental structure he or she brought to the event. However, the viewer's awareness of the "aperture" interpretation of the display alone, was not in itself responsible for the effect. Given the same description of the display, perception of the moving cross did not occur when the sequence of successive views was presented more rapidly (e.g., 10 views/second). In this case visual integration occurred, causing the successive views to summate. The demonstration was successful only when presentation rates of at least 2-3 views/second were used (Hochberg, 1986). The slower rates are more consistent with the rate at which viewers shift their fixation during visual scanning (e.g., Yarbus, 1967). At these rates, sensory/perceptual integration was not evident, and viewers apparently were able to make use of the proposed mental schema.

This demonstration illustrates the primary difference between the mental schema proposed by Hochberg (1978, 1986), and the type of visual representation proposed by Davidson, Fox, and Dick (1973). The schema is not considered to be sensory or photographic in nature. Instead, successive views are thought to be stored in a more abstract format. Hochberg (1986) points out that during visual scanning, many visual details may simply go unnoticed and may be unrepresented in the schema. He illustrates this point with a scene from the movie, "Nights of Cabiria". In a two-shot series of close-ups, a truck which was visible over the shoulder of an actor disappeared from one cut to the next -- a "disappearing act" that viewers of the film simply do not notice. The mental schema maintains important spatial and form-related information, without being a sensory representation.

To summarize, the mental schema is considered to be a part of the perceptual process. This schema provides the viewer with the means for comprehending successive views, and allows the viewer to grasp the structure of a visual world that is never visually present all at once, but "exists" beyond the boundaries of each successive view. In visual scanning, the schema would provide expectations about the probable layout of the next eye fixation, as well as providing a spatially organized storage system for incorporating information gleaned from successive glimpses of the world. This structure is so important to the final perception, that Hochberg (1986) argues that "... the schematic events that the viewer has in mind and can bring to the moving picture are, in normal usage, at least as important as the stimulus information, regardless of how sophisticated the analysis of the latter" (p 48).

The perceptual schema, however, is difficult to study. Hochberg's analysis of film and video editing provides one means for inferring its nature. Another possible means of studying the perceptual schema may come from a recently reported picture memory phenomenon called, "boundary extension".

3. Boundary Extension

What is the mental representation of a picture like? How well do people actually recollect the details and the layout of a picture? The possibility that drawings might provide insight into pictorial representation led me to study students' drawings of previously viewed photographs. Although their artistic competence varied widely, I began to notice that their drawings all seemed to contain the same error. In photographic terms, their drawings depicted a more wide-angle view of the scene than had been captured in the photograph. Put another way, nearly all the drawings contained visual information that is likely to have existed just outside the camera's field of view, but that had not been present in the photograph they had studied. I refer to this error as "boundary extension", because the subjects had apparently extended the boundaries of the picture. The question of why this error was the rule rather than the exception was intriguing, but the most interesting aspect of the phenomenon for me was the possibility that memory of a picture might include information drawn from a perceptual schema that was active during picture perception.

Intraub & Richardson (1989) recently conducted a formal test of this observation. First, we replicated it using drawing tasks, then we demonstrated that the same memory error was evident in recognition tests as well. In these experiments, we tested memory for close-up views of natural scenes following relatively long retention intervals (35 minutes or 2 days). The results clearly showed a unidirectional distortion of picture boundaries in recall and recognition of previously viewed photographs.

In one experiment, 37 subjects were presented with close-up photographs (35 mm slides) of 20 common scenes for 15 seconds each. In all the scenes the main objects had been cropped by at least one of the picture's edges (for an example, see Figure 1, panel A). They were instructed to remember each picture in as much detail as possible, and to consider the background to be as important as the foreground. After a 35 minute retention interval, subjects were provided with response sheets containing rectangles bearing the same aspect ratio as a 35 mm slide (1:1.5). They were instructed to draw four of the pictures. Each picture was to be drawn within one of the 4" x 6" rectangles. They were told to consider the edges of the rectangle to be the edges of the photograph and to draw the pictures accordingly.

Although all of the photographs contained main objects that were cropped, subjects did not depict them in this way in their drawings. Instead, they completed the main object(s) and added more background information between them and the picture's edges than had actually been the case. Using conservative criteria (see Intraub and Richardson, 1989), judges rated each drawing. Out of 133 drawings, 95% clearly showed boundary extension. The remaining 5% were either rated as accurate or as showing boundary restriction.

A second experiment was carried out to determine if completion of the cropped main objects was causing the distortion. Two versions of each scene were prepared: One in which the main objects were slightly cropped, and one in which they were not (see the photographs in Figure 1). Forty-one subjects were presented with the same 20 scenes for 15 seconds each. Half were shown in their cropped version and half were shown in their slightly wider-angle uncropped version. Across subjects, scenes were presented in each version equally often. After 48 hours, subjects were asked to draw up to 6 of the pictures. Again, they were instructed to lay out the picture in the rectangle so that the edges were the same as in the stimulus. The results showed that regardless of whether or not the main objects were cropped, subjects tended to extend the boundaries of the stimuli. Boundary extension was evident in 96% of the drawings associated with the cropped stimulus versions, and in 87% of the drawings associated with the wider-angle stimulus versions.

Two representative drawings are shown in Figure 1. To evaluate the drawings, it is important to look at the pictures' edges -- first at the photograph and then at the drawing. It is interesting to note that the typical drawing of the cropped close-up (panel C) looks like the wider-angle photograph (panel B) that the subject did not see. The typical drawing of the wider-angle photograph (panel D), is an even more wide-angle depiction. Apparently, subjects were not simply drawing an uncropped view of the main objects. Whatever boundaries the edges of the photograph had imposed, subjects depicted them as having revealed more of the scene than had actually been the case.

Intraub and Richardson (1989) demonstrated that this unidirectional distortion was not an artifact of the drawing task. The same distortion was evident in a recognition test in which subjects rated test pictures (targets and distractors) in terms of how similar their boundaries were to the boundaries of the presentation pictures. In this experiment, pairs of scenes such as the example in Figure 1 were used in the following way.

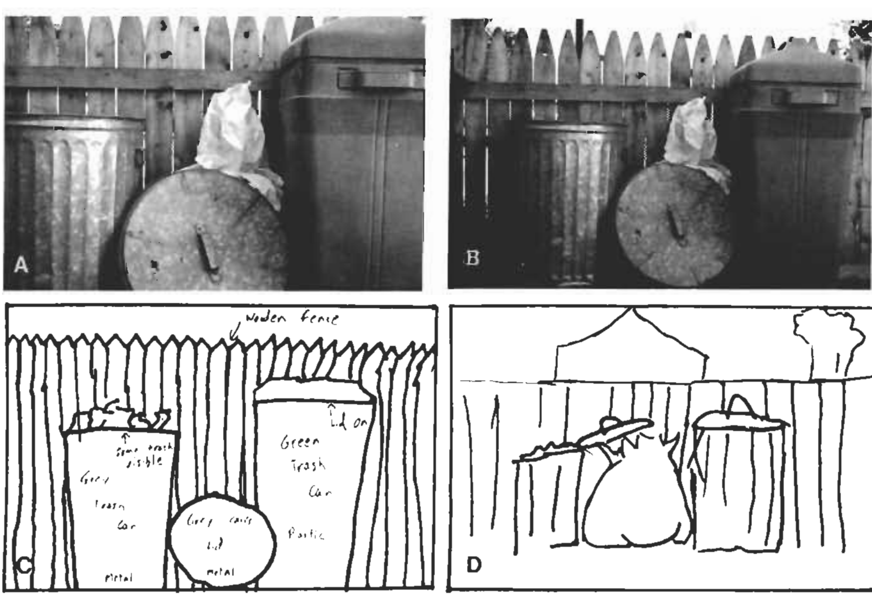

Fig. 1. Scene pair and representative drawings showing boundary extension. Panel A shows a close-up version of the scene with main objects cropped. Panel B shows a slightly more wide-angle version of the same scene with main objects uncropped. The drawings in Panels C and D are representative drawings of the photographs in Panels A and B, respectively. The actual photographs were in color. The subjects' original drawings were in pencil; these were photocopied and all lines darkened for this figure. (From Intraub & Richardson (1989), copyright 1989 by the American Psychological Association. Adapted by permission.)

Eighty-five subjects viewed 20 photographs of scenes for 15 seconds each: 10 in their relatively close version, and 10 in their slightly wider-angle version. Two days later, subjects were presented with the same 20 scenes in the same order of presentation. Half the scenes were presented in the original version and half were presented in the other version. They were asked to rate each test picture on a 5-point scale as "a lot closer-up" (-2), "a little closer up" (-1), "the same" (0), "a little further away (+1)", or "a lot further away" (+2).

Subjects' responses showed that their pictorial representations of the pictures contained extended boundaries. They tended to rate the same pictures as being "closer-up" than before. This response to seeing the *same* picture again, indicated that the subject's representation of that picture had extended boundaries. Subjects made significantly more boundary extension responses than boundary restriction responses. This was particularly pronounced for the closer views which were rated as closer than before 65% of the time, and wider than before only 3% of the time. The average rating on the 5-point scale was -.68 for the closer pictures, and -.12 for the wider-angle pictures. The pattern of responses elicited by the distractors also indicated that subjects were remembering the pictures with extended boundaries.

Given two versions of the same scene, an asymmetry was observed depending on whether the closer version was the stimulus and the slightly wider version was the distractor, or vice versa. Once again, refer to the stimulus pair in Figure 1 (panels A and B). When the wider-angle version was the distractor, it was rated as closer to "same" (.24) than when the closer version was the distractor (-1.30). This asymmetry is the logical result of a unidirectional distortion. If the presentation picture is remembered with extended boundaries, a wider-angle distractor would be expected to more closely match the subject's recollection than a distractor showing a closer view. The same pair of pictures were responded to differently depending on which was remembered and which served as the test item.

The key observations in these experiments are: 1) Subjects did not simply exhibit poor memory for picture boundaries -- sometimes calling a picture a little closer up and sometimes calling it a little further away. Their errors tended to be unidirectional, yielding boundary extension. 2) Both versions of the scenes used in these experiments can be described as close-ups and both versions yielded boundary extension. The closer versions, however, yielded a greater degree of extension than the slightly wider versions. This was the case in the recognition test and was also reflected in the recall (drawing) task.

The nature of the distortion is intriguing in the light of the discussion of the perceptual schema. One hypothesis is that when perceiving the picture, a schema, extending beyond the picture's boundaries, is activated during comprehension of the close-up view of a natural scene. This schema is so important to the comprehension of the picture, that it becomes incorporated into the subject's recollection of the picture. Highly probable parts of the schema are remembered as having been physically present. There are however, two other strong alternate explanations, one having to do with normalization processes in memory (memory schema), and one having to do with the completion of background objects.

4. Boundary Extension and the Perceptual Schema

Three alternative explanations of boundary extension will be discussed in this section: the perceptual schema hypothesis, the memory schema hypothesis, and object completion.

Perceptual Schema Hypothesis. The perceptual schema hypothesis is predicated on two assumptions. The first is that picture perception involves the activation of a perceptual schema that extends beyond the picture's boundaries. The second is that perceptual expectancies contained in that schema may become incorporated into the subject's recollection of the picture. Consistent with the view that the mental schema is as important to perception as the actual stimulus input, in memory the observer cannot distinguish between the two. In addition to the depicted information, the subject recollects having seen the highly probable information that he or she had previously "perceived" as existing just outside the picture's boundaries.

Intraub and Richardson's (1989) observation that slightly wider-angle pictures yielded less extension than the closer views can be explained by this hypothesis. Consider several views of a centrally located object, ranging from a close-up view to a wide-angle view. In the case of a tight close-up, highly probable surrounding information will not be captured in the photograph. It will, however, be represented in the subject's mental schema during perception of the picture and in fact is critical to the observer's comprehension. As more wide-angle views of the same object are presented, more of the probable surrounding area will be contained within the picture itself.

As a result, boundary extension would be greatest for close-ups and would decrease for increasingly wide-angle views. At some point, a view might become wide enough for the amount of extension to asymptote, and in fact there may be a point at which no *directional* error would be obtained. Subjects would sometimes consider the picture to be "just a little closer up than before" and sometimes, "just a little further away." This model would predict overall boundary *restriction* for none of the picture types. Put another way, if a picture can be thought of as analogous to the information in a single eye fixation, then comprehension of the picture may include the expectation of what the next eye fixation would be likely to bring into view. This means that whenever there is a directional distortion it should move the boundaries outward -- not inward to yield restriction.

Memory Schema Hypothesis. According to the memory schema hypothesis, boundary extension reflects a process of normalization in memory that can be thought of as "regression to the prototype" (cf. Bartlett, 1932; E. Gibson, 1969). Subjects may have an expectation about a standard view of an object. The close-ups used in Intraub and Richardson's (1989) experiments, are by definition closer than "the standard view". Over time, the subject's representation becomes biased toward the prototypic viewing distance. As a result, a close-up is remembered as having been less of a close-up.

This hypothesis provides a different explanation of why the wider versions yielded less extension than the closer versions in Intraub and Richardson's (1989) experiments. The wider versions were closer to being prototypic to begin with, and therefore underwent a less dramatic transformation as they normalized. Following this logic, the memory schema hypothesis leads to a different prediction than the perceptual schema hypothesis, regarding the presentation of increasingly wide-angle views.

If we begin with close-ups, then, according to this hypothesis, as increasingly wide-angle views are presented subjects should show decreasing boundary extension, reaching no directional distortion for prototypic pictures, and then reversing toward increasing degrees of boundary *restriction* as more wide-angle views are presented.

To summarize, the perceptual schema hypothesis attributes boundary extension to the initial comprehension of a picture which includes schematic expectations about information just outside the picture's boundaries. Alternatively, the memory schema hypothesis attributes the phenomenon to normalization of the representation toward a prototypic viewing distance.

Each can account for the results of Intraub and Richardson (1989), but each predicts a very different pattern of results regarding memory for prototypic and wide-angle pictures.

Object Completion. In the wider-angle versions of the pictures used by Intraub and Richardson (1989), although the main objects were not cropped by the picture's edges, the edges frequently cropped background objects, such as the door to a room or a window in the background, etc. For this reason, the Gestalt principle of object completion (cf. Ellis, 1955) was considered as a possible explanation of boundary extension. Intraub and Richardson (1989) tentatively argued against object completion as the cause of boundary extension based upon some characteristics of their subjects' drawings (e.g., subjects frequently extended boundaries without completing the cropped objects -- they simply drew more of the object than had appeared in the original picture). To provide a direct test of the hypothesis, however, it would be important to determine if boundary extension would occur if there were no cropped background objects. All of the following experiments made use of new stimuli that met this requirement. If boundary extension is caused by a tendency to complete background objects, then no boundary extension should be obtained with these new pictures.

5. New Boundary Extension Research

Intraub, Bender, and Mangels (1992) conducted a series of experiments to determine whether boundary extension reflects object completion, normalization to an expected viewing distance, or the activity of a perceptual schema during picture perception. To test these three hypotheses, a new stimulus set was created that will be described shortly. In addressing the two schema hypotheses, Intraub, et. al. (1992) considered the possibility that both the perceptual schema and the memory schema might affect pictorial representation, but that these effects might follow different time courses. Specifically, the effects of a perceptual schema might be more readily apparent immediately following presentation, whereas the effects of a memory schema (normalization toward a prototypic viewing distance) might take place over a longer period of time. To test this possibility, boundary memory was tested immediately as well as after a 2-day delay.

To create a stimulus set that would allow a test of the three hypotheses, 22 scenes were photographed in three different versions: close-up, medium, and wide-angle. The pictures always contained a main object (or objects) against a natural, textured background that contained no incomplete objects (e.g., asphalt, brick, grass, carpeting, tile, etc.). Fifty-eight subjects rated the pictures on a 5-point scale that ranged from -2 to +2, to indicate if a picture depicted a standard view of the object (0), was too close-up to be standard (-1 or -2, depending on degree), or was too far away to be standard (+1 or +2). Each subject was presented with one version of each of the 22 scenes. Sixteen of the scenes were selected for the new stimulus set based on the group ratings. The mean ratings for close-ups, prototypes, and wide-angle pictures in this set were -.42, -.02, and +1.53, respectively. Although the photographs in Figure 2 are from a more recent picture set (to be described later), they are similar to the scenes used by Intraub et al. (1992), and will give a good indication of what the stimuli looked like.

Intraub et al. (1992) replicated the boundary extension effect with close-ups from the new stimulus set using the same procedure as in the previous research. Although the new scenes were more simple than those presented by Intraub and Richardson (1989), the new close-ups yielded a comparable degree of boundary extension. Across experiments, the new stimulus set yielded no support for the object completion hypothesis. Boundary extension was readily apparent in memory for pictures that had contained no cropped background objects. Subjects continued to rate the same view as being "closer-up" than before, even though the backgrounds were homogeneous. They simply recollected having seen more of the background.

A test of the predictions of the two schema hypotheses was conducted in two experiments, each including both an immediate and 2-day delay condition. In the first of the immediate/delay experiments, we presented subjects with prototypic and wide-angle pictures, using the same basic design as Intraub and Richardson (1989). Subjects in this experiment viewed 16 scenes (half in their prototypic version and half in their wide-angle version). Half the subjects were tested immediately after presentation, and half were tested after a 2-day delay. In the recognition test half of the pictures were presented in the original version (targets) and half in the other version (distractors). Subjects rated each picture on the same 5-point scale described previously.

Boundary extension was evident within minutes of presentation. When memory was tested immediately, the pattern of results clearly supported the perceptual schema hypothesis; prototypes were remembered with extended boundaries (mean rating = -.13), and the wide-angle pictures yielded no directional distortion (mean rating = -.03). It is important to note that the wide-angle pictures were *not* remembered more accurately than the prototypes - the hit rate (correctly rating the pictures as "same") for the two versions did not differ. What differed was that when subjects saw the prototypes again, they made significantly more extension errors than restriction errors, whereas when they saw the same wide-angle picture again, their errors were equally distributed, yielding no directional bias.

When memory was tested after a two day delay, a different pattern of results was obtained. Consistent with the memory schema hypothesis, wide-angle pictures were remembered with *restricted* boundaries - yielding a mean rating of +.32. Upon viewing the same wide-angle pictures in the test, subjects made significantly more restriction responses than extension responses. They tended to rate the wide-angle pictures as being "further away" than before, thus indicating that they remembered those pictures as having had more restricted boundaries. However, the results only partially supported the memory schema hypothesis. Contrary to one of the predictions, the prototypic pictures yielded boundary extension. In fact, boundary extension for the prototypes increased over time, yielding a mean score of -.25. One possibility was that in spite of what was indicated by the normative ratings, the prototypes might not actually have been prototypic. Another possibility, however, was that the memory schema hypothesis required modification.

A second experiment was conducted in order to replicate and extend the results of the immediate condition, as well as to explore an alternative memory schema hypothesis. The alternate hypothesis was suggested by the symmetry of the delay results. Perhaps, over time, the pictorial representations normalize toward the average view depicted in the stimulus set, rather than toward a prototypic viewing distance. That is, the pictorial representations may have normalized toward an average of the prototypic and wide-angle views presented. In this experiment, therefore to avoid the averaging of extremely different views, subjects viewed only one picture type: close-up, prototypic, or wide-angle. The question was whether boundary extension would be observed for relatively homogeneous picture sets. Of particular interest, given the memory schema hypothesis, was whether it would occur for prototypes under these conditions.

One hundred and thirty subjects were divided into three groups. Each group was presented with either the close-up, prototypic, or wide angle version of all 16 scenes for 15 seconds each. Half of the subjects were tested immediately, and half were tested after a two-day delay. To avoid any contamination of memory through the introduction of other versions at any point in the experiment, the recognition test sequence contained the same 16 pictures as the presentation sequence with no distractor items. Subjects were told that the same scenes would be presented but that sometimes they might be slightly more wide-angle or slighter more close-up versions. They were instructed to rate each picture on the same 5-point scale used in the prior research to indicate if the pictures were the same as before (0), closer up than before or more wide-angle than before. If the prototypes in the previous experiment had yielded boundary extension because they were mixed with wide-angle pictures, then they should show no boundary extension in an experiment in which they are presented alone.

The immediate condition provided clear support for the perceptual schema hypothesis: when different picture types were not mixed together, boundary extension was obtained for close-ups, prototypes, and wide-angle views. The results were all the more striking because the subjects were viewing the *same* 16 pictures within minutes of their initial presentation. In all three conditions, subjects made significantly more boundary extension errors than restriction errors. Furthermore, the degree of extension decreased significantly as increasingly wide-angle views were presented. The mean ratings obtained for each picture type at both retention intervals are presented in Table 1.

The decrease in boundary extension with increasingly wide-angle views could not be attributed to better memory for the wider-angle versions, because as in the previous experiment, the hit rate (number of pictures correctly identified as "same") did not differ among the three conditions. When tested immediately, subjects' recollections of pictures tended to have extended boundaries and did not seem to be influenced by normalization to an expected view. Contrary to the memory schema hypothesis, none of the picture types yielded boundary restriction, and pictures in the prototypic range yielded boundary extension.

As in the previous experiment, a 2-day delay resulted in a different pattern of errors. As shown in Table 1, following a delay, wide-angle pictures now yielded boundary restriction. The directional distortion was small but significant. Unlike the previous experiment (in which picture versions were mixed), all three picture types showed a decrease in extension over time. This was not due to increased accuracy after a delay, but to an increase in the number of restriction responses. This "restrictive shift" occurred for all three stimulus types and led to a small but significant bias toward restriction for the wide-angle pictures.

Table. 1. Mean Boundary Ratings for Close, Prototypic, and Wide-Angle Pictures as a Function of Retention Interval when Picture Versions were Unmixed

Retention Interval	Close	Picture Version Prototype	Wide
Immediate	-.45	-.34	-.17
Delay	-.28	-.20	.07

The pattern of results in these experiments suggests a two-component model of the representation of pictorial views. Shortly after studying pictures, observers remember them with extended boundaries. According to the model, this unidirectional distortion of the boundaries reflects the activation of a perceptual schema during picture comprehension. Highly probable scene information that was not visually present is included in the subject's recollection of the picture. Over time, however, the representation undergoes a transformation in memory. Contrary to the memory schema hypothesis, this transformation does not appear to include normalization to an expected viewing distance for the objects. What it may include is an interaction of the early effects of the perceptual schema (which tends to move the boundaries out) with a tendency for the pictures to normalize toward the average of the set (even within a very similar set, such as that used in the present experiment).

This latter view was supported by the results of a condition in which the same pictures were presented with slightly more wide-angle versions of other pictures, in a set that on average was rated as prototypic, or were presented with slightly more close-up versions of other pictures, in a set that on average was rated as close-up. The results showed that although the pictures all yielded extension, they yielded a greater degree of extension when presented with slightly wider pictures than with slightly closer pictures. Future experiments will analyze the changes in boundary distortion over a wider range of retention intervals to provide a better understanding of the nature of the transformation in memory. The most interesting outcome of the research for the present discussion, however, is the support for the perceptual schema hypothesis in the immediate conditions. Within minutes of viewing photographs subjects remembered them with extended boundaries and the size of the boundary effect was associated with the picture view.

In ongoing research with Deborah Berkowits, we have continued to explore immediate memory for picture boundaries. We have just completed an experiment designed to replicate the immediate results of Intraub et al. (1992) in recall using a drawing task. Two questions of primary interest were whether observers would draw extended boundaries for close-ups, prototypes and wide-angle pictures within minutes of viewing them and whether this would happen if a small stimulus set of only 7 items was presented. Of secondary interest was the introduction of a new stimulus set in which a more conservative estimate of prototypic pictures was used, as a final replication of the observation that prototypic pictures do indeed yield extended boundaries.

Out of a new set of 42 scenes (with 5 versions each), seven scenes were selected that exhibited high subject agreement on which version was prototypic, too close-up to be prototypic and too wide-angle to be prototypic. Once again, no cropped background objects were included in the pictures. The mean boundary ratings for the close-up and wide-angle versions were -1.10 and +1.10, respectively, and the mean rating for the prototypes was -.08. These "prototypes" had yielded higher subject agreement than in the previous experiment (mean agreement = 80%). The photographs in Figure 2 are from this stimulus set, and show the three versions of the "basketball scene".

Subjects were presented with either 7 close-ups, 7 prototypes, or 7 wide-angle pictures for 15 seconds each. As in the earlier experiments, they were told to make an exact copy of the picture in memory and to remember the foreground and the background in as much detail as possible. Immediately following presentation, they were asked to draw each of the seven stimuli. A booklet containing 4" x 6" rectangles was provided, along with the name of each scene in the order of presentation viewed by that subject. After drawing the pictures, the subjects were presented with the same stimuli again in a recognition test and rated each of the 7 pictures on the same 5-point scale used previously. There were 49-50 subjects in each of the 3 conditions (close-up, prototype, wide-angle) who participated in groups of up to 6 at a time.

The drawings provided dramatic support for the perceptual schema hypothesis. Immediately after viewing 7 slides for 15 seconds each, subjects' drawings revealed pronounced boundary extension for the close-ups *and* the prototypes, and revealed no directional distortion for the wide-angle pictures. Sample drawings are presented in Figure 2.

Instead of judges evaluating each drawing with respect to a set of criteria, a quantitative measure of the distortion was evaluated. The area of each main object drawn, was estimated by tracing the object onto graph paper (10 boxes to the inch) and counting the boxes and partial boxes on the grid. The area of the stimulus object was determined by projecting the stimulus slide onto the same grid with the same dimensions as the drawings (4" x 6"). The mean proportion of the stimulus object's area drawn by the subjects for each picture, in each of the three conditions, is presented in Table 2. On average, subjects extended the boundaries of the close-up views such that the main object took up only about 1/3 of the area taken by the stimulus object in the photograph. For prototypes, the drawn object took up only about 4/10 of the stimulus object. In the case of wide angles, no directional distortion was

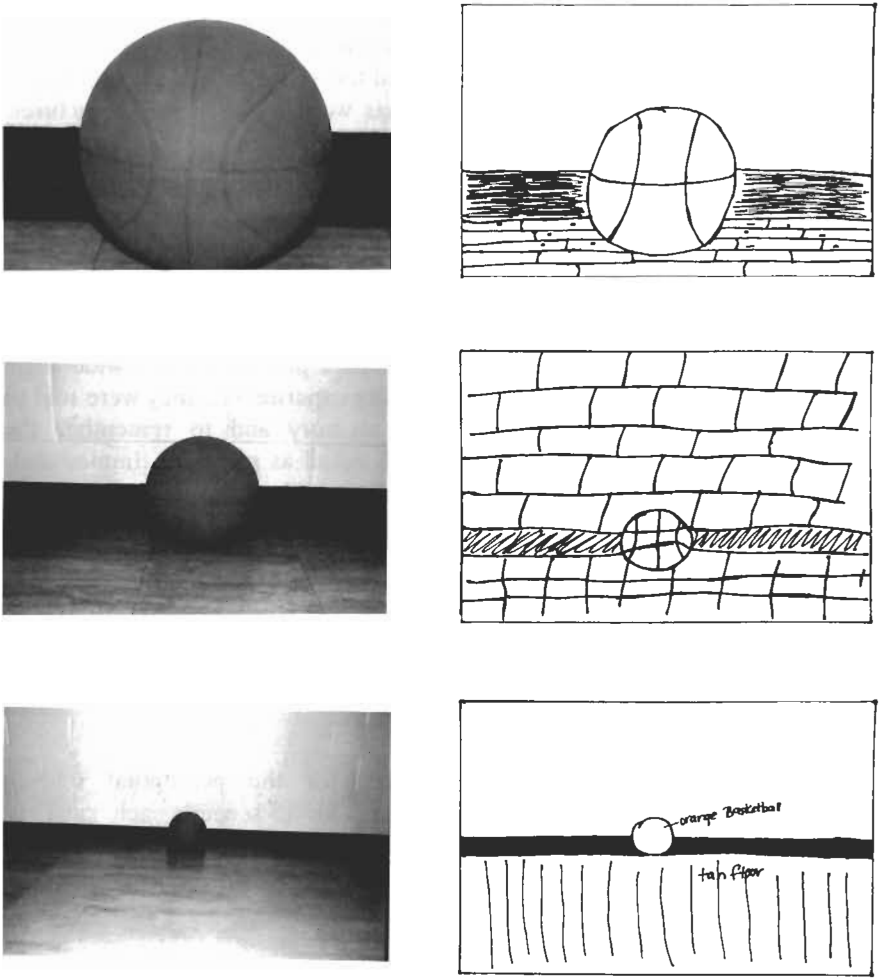

Fig. 2. Three versions of the "basketball scene" with a representative drawing for each. From top to bottom, the figure shows the close-up and prototypic versions (with representative drawings showing boundary extension), and the wide-angle version (with a representative drawing showing no directional distortion.) The actual photographs were in color. Subjects original drawings were in pencil; these were photocopied and all lines darkened for this figure.

Out of a new set of 42 scenes (with 5 versions each), seven scenes were selected that exhibited high subject agreement on which version was prototypic, too close-up to be prototypic and too wide-angle to be prototypic. Once again, no cropped background objects were included in the pictures. The mean boundary ratings for the close-up and wide-angle versions were -1.10 and +1.10, respectively, and the mean rating for the prototypes was -.08. These "prototypes" had yielded higher subject agreement than in the previous experiment (mean agreement = 80%). The photographs in Figure 2 are from this stimulus set, and show the three versions of the "basketball scene".

Subjects were presented with either 7 close-ups, 7 prototypes, or 7 wide-angle pictures for 15 seconds each. As in the earlier experiments, they were told to make an exact copy of the picture in memory and to remember the foreground and the background in as much detail as possible. Immediately following presentation, they were asked to draw each of the seven stimuli. A booklet containing 4" x 6" rectangles was provided, along with the name of each scene in the order of presentation viewed by that subject. After drawing the pictures, the subjects were presented with the same stimuli again in a recognition test and rated each of the 7 pictures on the same 5-point scale used previously. There were 49-50 subjects in each of the 3 conditions (close-up, prototype, wide-angle) who participated in groups of up to 6 at a time.

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Table 2. The Average Proportion of the Stimulus Object Depicted in the Drawing for each Version (Close-Up, Prototype, and Wide-Angle) of each of the Seven Scenes

	Scene						
Version	Basketball	Bear	Bananas	Tire	Sneakers	Pail	Crayons
Close-up	.43	.34	.26	.44	.36	.41	.22
Prototype	.66	.29	.30	.44	.39	.37	.42
Wide-angle	1.98	1.24	.78	1.20	.81	.68	.53

In the close-up condition, as may be seen in Table 2, each of the seven pictures showed considerable boundary extension. Out of 343 drawings, made by 49 subjects, only 4 drawings depicted an object that matched or exceeded the size of the original. In all the close-up photographs, the main objects had either touched or been slightly cropped by at least one of the picture's edges, yet subjects drew the objects as uncropped, and depicted a considerably more wide-angle view of each scene. Furthermore, subjects obviously had paid attention to the background, because they correctly drew the background that had immediatly surrounded the object -- their error was in drawing a greater expanse of background than had actually been the case.

In accordance with the perceptual schema hypothesis, the prototypic pictures were also remembered with extended boundaries, and the effect was slightly less pronounced than for the close-ups. Out of 350 drawings made by 50 subjects, all but 13 had extended boundaries. The drawings contradicted the memory schema hypothesis' prediction that pictures that already represent the prototypic view should yield no directional distortion; recall that on average the boundaries were extended enough to shrink the main object to 40% of its actual size in the picture space. Comparison of the drawings in the close-up and prototype conditions shows that subjects were not simply drawing an idealized version of the scene. If this had been the case, one would expect to see similar drawings regardless of whether the subject had seen the close-up version or the prototypic version. Instead, whatever boundaries the stimulus picture had placed on the scene, the subjects seemed to extend those boundaries further.

Subjects' drawings of wide-angle pictures yielded no directional distortion. This does not mean that subjects were accurate on each picture. Unlike the other two picture versions, there were many instances of restriction as well as extension for all the pictures. If anything there was a slight bias toward extension, in that four of the pictures tended to be drawn with extended boundaries and three with restricted boundaries (see Table 2). An interesting observation was that the stimuli containing main objects that covered the smallest amount of picture space tended to be the ones yielding restriction, whereas the stimuli with main objects that covered a larger area of the picture space tended to yield extension. (This may be seen in Table 2 in which the pictures are listed in descending size order of the main objects in the wide-angle condition). This observation supports Intraub et al.'s (1992) suggestion that when the effect of the perceptual schema is not strong, the pictures will tend to normalize toward the average of the picture set.

The drawing task took subjects approximately 20 minutes to complete. Following this they were given the same recognition test as in the unmixed condition of the Intraub et. al. (1992) experiment. All seven pictures were presented again and subjects rated each one on the 5-point scale. The results replicated those of the earlier experiment. Subjects made significantly more extension than restriction responses for all three stimulus types (Wilcoxon tests, $p < .001$, all cases) and the mean extension rating decreased significantly as increasingly wide-angle views were presented, $F\ (2,151) = 14.35$, $MSE = .12$, $p < .001$. Mean boundary ratings were -.66, -.40, and -.30, for the close-up, prototypic, and wide-angle pictures, respectively.

These results and the results of the immediate tests conducted by Intraub et al. (1992), all support the perceptual schema hypothesis. They support the view that boundary extension is the result of the activation of a scene schema during picture perception -- a schema that represents the likely structure of the scene that "exists" just beyond the picture's boundaries. It is this schema, in conjunction with visual analysis of the stimulus, that allows us to perceive a picture (particularly a close-up) as depicting only a part of a scene. As pointed out earlier, when we view a portrait, we perceive not only the details of the face, but that the rest of the person and the rest of the scene continue beyond the picture's boundaries. The schema is such an integral part of the perception of the picture, that subjects have difficulty in recalling or recognizing the picture's actual boundaries, and tend to incorporate the schema into their recollection. This moves the boundaries outward and results in boundary extension.

6. Implications for eye movements

The results of the boundary extension experiments suggest that a perceptual schema is important to picture perception and memory. If we grant the analogy between a picture and an eye fixation raised at the beginning of the chapter, the possibility that this schema may play a role in the integration of successive eye fixations can be considered. The first question that must be addressed in evaluating this possibility is whether the rapid, dynamic nature of visual scanning is compatible with the use of such a schema. After all, subjects can fixate a display up to 3-4 times per second. Yarbus (1967), for example, reported that subjects make approximately 3 eye fixations per second when studying a scene. It is necessary to consider whether there would be enough time available between the onset of one fixation and the onset of the next; a) to generate a schematic structure, and b) to make use of it to interrelate successive views. The picture perception literature provides some strong insights into these questions.

In one line of research, using tachistoscopic presentation of pictures, Biederman and his colleagues (e.g., Biederman, 1981; Biederman, Mezzanotte, & Rabinowitz, 1982) have demonstrated that the "gist" of a complex outline scene is perceived with remarkable rapidity. For example, Biederman et al. (1982) presented subjects with outline drawings of scenes for 150 msec each, followed by a mask and a visual cue. Subjects had to indicate whether the cued object corresponded to an object named at the trial's onset. Object identification took longer and was less accurate when the object appeared in an improbable context (e.g., fire hydrant in kitchen) than in a probable one (e.g., fire hydrant in street scene), even though it was presented in the same spatial location on the screen. They argued that gist acquisition had occurred rapidly enough to affect the viewer's speed and accuracy in identifying a specified object *within* this briefly glimpsed scene.

Based on similar experiments, Biederman (1981) has proposed that knowledge of real world scenes includes two general types of relationships among objects that can be referred to as "physical" and "semantic". He argued that in a meaningful scene, objects must follow physical laws of placement (e.g, they are supported, and they occlude the background). They also must follow semantic laws related to their identity (e.g., regarding their size or position with respect to other objects in the scene, and their probability of appearing in such a scene). He and his colleagues (e.g., Biederman, 1981; Biederman, Mezzanotte, & Rabinowitz, 1982) have studied the effects of violating these proposed physical and semantic expectations on the speed and accuracy of object identification. Using the same basic design described earlier, they demonstrated that violations of support, size, location, superposition, or probability all slowed or disrupted identification of a visually cued object in displays presented for only 150 msec. Violation of more than one of these laws at a time yielded even more interference with object identification.

This research strongly suggested that subjects' comprehension of briefly flashed outline scenes was not based upon identification of single objects, but that the physical and conceptual structure of the scene was grasped at a more general level. This relatively abstract "gist" could then guide perception of specific details within the scene. Biederman (1981) has likened this general scene knowledge to the concept of "deep structure" in language comprehension. Because the "gist" and the rules of scene structure affected object identification given such a briefly presented, masked stimulus, it seems plausible that these processes could take place for each fixation during visual scanning. Picture perception experiments using dynamic presentations of sequential stimuli, carry this point further.

Visual search experiments, using high-speed presentation of pictures, have demonstrated that unrelated scenes can be understood at presentation rates that surpass the average fixation frequency of the eye (Intraub, 1981a, 1981b; Potter, 1976). In Potter's (1976) research, color photographs of scenes were presented at rates ranging from 113 to 333 msec per picture (with no interstimulus interval). Subjects were presented with a number of sequences, each containing 16 unrelated scenes. A picture in the sequence was cued either by being presented in advance to the subject or by being described using a brief verbal title (e.g., "a road with cars"). The rationale for using both visual and verbal cues was that in order to match the verbal cue, the subject would have to understand the picture's meaning, whereas a match with the visual cue could be made on the basis of physical characteristics alone. Comparison of the two conditions was thought to provide insight into how much the search task relies on specific visual expectancies versus actual scene comprehension. The proportion of targets detected based on the verbal cue was interpreted as reflecting the minimal proportion of pictures identified during presentation.

To indicate detection, subjects pressed a key as soon as they saw the cued picture in the sequence. Responses falling between 250 and 900 msec following target onset were counted as correct. Results showed that subjects could identify unrelated scenes remarkably well at presentation rates that were equivalent to the average eye fixation frequency, and at those that were considerably more rapid. On the basis of the verbal cue, detection accuracy for rates of 113, 167, 250 and 333 msec/picture was 64%, 74%, 89%, and 78%, respectively (the apparent decrease at the slowest rate was due to an increased number of anticipation responses). Performance with the verbal cue was almost as good as seeing the picture itself in advance. These results showed that completely unrelated scenes presented at rates equal to or faster than the average fixation frequency of the eye could be conceptually analyzed and matched to a verbal cue. These results were replicated and extended by Intraub (1981b) using a number of design modifications, providing a further demonstration of the viewer's ability to rapidly grasp the meaning of a picture.

Intraub (1981b) used a "negative detection" task to determine if observers could identify unrelated photographs presented at high speeds, without receiving any direct information regarding their probable physical features. Although Potter (1976) had used general titles, one could argue that "a road with cars" narrows the visual expectations of the viewer and may enhance perception of the target picture. To minimize expectancy, in the negative detection experiment, a diverse set of 11 objects from a single general category and 1 picture (the target) that was not from that category were presented in rapid succession. Sequences were presented at rates of 114, 172, and 258 msec/picture. Photographs were selected that were as visually dissimilar as possible. For example, the category "animals" contained creatures as diverse as a frog, a dog, a giraffe, and a butterfly. The target picture did not differ in size or general color from the other pictures in the set. The cue provided at the beginning of each sequence was a "negative cue", for example, "the picture that is *not* an animal". Because no information about the target object was provided, correct detection responses were based upon the subject's description of the target, rather than inferring responses from reaction times. (Although reaction time was measured as well.) The results were consistent with those of Potter (1976).

Subjects were able to detect and describe target pictures surprisingly well at all three rates, without having been provided with any specific information about their visual characteristics. At the rate most closely approaching the average eye fixation frequency (258 msec/picture), 79% of all targets were detected with the negative cue. When the rate was increased to 172 and 114 msec per picture, far faster than observers can shift fixation during visual scanning, 58% and 35% of the targets were detected, respectively.

The search experiments show that a sizeable proportion of completely unrelated views can be rapidly understood when presented at rates of 3-4 pictures per second. Considering the fact that successive eye fixations on a real-world scene present the viewer with highly related, redundant, and overlapping views, the likelihood is that the ability to perceive the meaning and structure of each successive input is very high. Biederman's (1981) observations, taken in conjunction with the search experiments, paint a picture of rapid schematic analysis during briefly glimpsed pictorial presentations. This is consistent with Hochberg's (1978, 1986) proposal of a mental schema that guides and integrates successive views during motion picture viewing.

Returning to Hochberg's (1986) discussion of the use of a mental schema in aperture viewing, it is worthwhile to consider one other temporal aspect of picture processing. Recall that in the aperture demonstration, when subjects were informed that the ambiguous display they would see was actually an outline cross moving behind an aperture, they could only perceive the display as such when the presentation rate was 2-3 views per second. At more rapid rates of presentation the views became visually integrated and could not each be evaluated in terms of the mental schema (e.g., at 10 views per second). Using photographs and outline drawings of scenes like those used in the experiments just described, Intraub (1985, 1989) has reported perceptual integration of components of temporally adjacent displays at a similar presentation rate (9 pictures/sec).

For example, Intraub (1985) presented subjects with color photographs of objects at a rate of 9 picture/second. They were instructed to report which object in each 12-picture sequence was surrounded with a black outline frame. Although subjects were often confident and correct (50-70% of the time), they were frequently confident and wrong. Subjects, when wrong, almost always reported the immediately preceding or immediately following object in the sequence as the one with the frame. It was demonstrated that when subjects made an error, they often reported the target object (the one actually in the black frame) as a "frameless" picture. A similar effect was obtained when subjects were required to search for a specified object in a sequence of outline scenes (Intraub, 1989). Yet if these stimuli are presented at a rate of 3-4 pictures per second, the searched-for element (frame or object) does not become integrated with temporally adjacent pictures. At rates such as these, the successive views have apparently reached a state of analysis that protects them from such visual intrusions. It is at this rate, if we consider Hochberg's aperture experiment, that individually glimpsed views can be matched to an abstract schema depicting the layout of a scene -- a scene that is only partially depicted in each single view.

Experiments designed to test the effect of context on the pattern and duration of eye fixations, have also provided evidence for early gist acquisition and have demonstrated a tendency for observers to fixate longer on improbable objects in scenes, perhaps in part because of the longer processing time required to identify them (Antes & Penland, 1981; Friedman, 1979; Loftus & Mackworth, 1978). To conclude, it seems reasonable to argue that the timing limitations imposed by the dynamic nature of visual scanning do not rule out the use of a perceptual schema to guide and integrate successive fixations.

In future research, we will test the existence of boundary extension following brief stimulus presentations that are similar to a single eye fixation in duration. If boundary extension plays a role in the comprehension of successive views, then it should be detectable this early in processing. It is encouraging to note that in a recent replication of the research conducted with Berkowits, we found that decreasing the presentation duration of close-ups from 15 sec each to 4 sec each, had no effect on the magnitude of the boundary extension effect, as tested using the recognition procedure.

Drawing data are currently being analyzed. Presentation durations in the range of 100 to 500 msec per picture have yet to be tested. In other research, we are attempting to isolate conditions that will affect the degree or direction of boundary distortion for a given picture type. Once this is determined, the eye movement patterns for the different conditions will be compared, to directly study the inter-relationship (if any) of the schema and the actual locations fixated in the picture space.

7. Conclusions

Observers tend to remember a picture as having shown more of a scene than had actually been the case. They incorporate into their recollection, information that would have been likely to have existed in the scene just outside of the picture's boundaries. This phenomenon, referred to as "boundary extension" can be observed both in drawings and in recognition tests within minutes of picture viewing.

New research was reported that supports the hypothesis that boundary extension is, in part, the result of the activation of a scene schema during picture perception. A picture depicts only a part of a scene and contains this partial information within its boundaries. Represented in the schema are expectations about the form and structure of the scene that "exist" just outside those boundaries. It was proposed that this same schema may provide the basis for the perception of successive views of a scene during visual scanning. If the input of each fixation is considered to be a "picture" whose boundaries are determined by limitations of visual acuity, then the perceptual schema would function much as it does in the case of picture perception. It could thereby provide an abstract spatial context for the integration of successive fixations.

Further research into the nature of boundary extension may therefore provide a new means for studying the cognitive representation of scenes and its impact on visual perception.

References

Antes, J. R., & Penland, J. G. (1981). Picture context effects on eye movement patterns. In D. F. Fisher, R. A. Monty, & J. W. Senders (Eds.), *Eye movements: Cognition and visual perception*. Erlbaum: Hillsdale, NJ.

Bartlett, F. (1932). *Remembering: A study of experimental and social psychology*. England: Cambridge University Press.

Biederman, I. (1981). On the semantics of a glance at a scene. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization*. Hillsdale, NJ: Erlbaum.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review, 94*, 115-147.

Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology, 14*, 143-177.

Davidson, M. L., Fox, M. J., & Dick, A. O. (1973). Effects of eye movements on backward masking and perceived location. *Perception and Psychophysics, 14* 110-116.

Ellis, W. D. (Ed., Trans). (1955). *A source book of Gestalt psychology*. London: Routledge & Kegan Paul.

Friedman, A. (1979). Framing pictures: The role of knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General, 108*, 316-355.

Gibson, E. (1969). *Principles of perceptual learning and development*. New BF 311. G48 York, NY: Appleton.

Gibson, J. J. (1950). *The perception of the visual world*. Boston: Houghton Mifflin.

Haber, R. N. (1983). The impending demise of the icon: A critique of the concept of iconic storage in visual information processing. *The Behavioral and Brain Sciences, 6*, 1-54.

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, pp. 22:1-22:64). New York: John Wiley & Sons.

Intraub, H. (1981a). Identification and processing of briefly glimpsed visual scenes. In D. F. Fisher, R. A. Monty, & J. W. Senders (Eds.), *Eye movements: Cognition and visual perception*. Erlbaum: Hillsdale, NJ.

Intraub, H. (1981b). Rapid conceptual identification of sequentially presented pictures. *Jounral of Experimental Psychology: Human Perception and Performance, 7*, 604-610.

Intraub, H. (1985). Visual dissociation: An illusory conjunction of pictures and forms. *Journal of Experimental Psychology: Human Perception and Performance, 11*, 431-442.

Intraub, H. (1989). Illusory conjunctions of forms, objects and scenes during rapid serial visual search. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*,98-109.

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

Intraub, H., & Richardson, M. (1989). Wide-angle memories of close-up scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*(2), 179-187.

Irwin, D. E., Brown, J. S., & Sun, J. (1988). Visual masking and visual integration across saccadic eye movements. *Journal of Experimental Psychology: General, 117*, 387.

Irwin, D. E., Yantis, S., & Jonides, J. (1983). Evidence against visual integration across saccadic eye movements. *Perception and Psychophysics, 34*, 49-57.

Loftus, G. R., & Mackworth, N. H. (1978). Cognitive determinants of fixation location during picture viewing. *Journal of Experimental Psychology: Human Perception and Performance, 4*, 565-572.

Neisser, U. (1967). *Cognitive psychology*. Appleton-Century-Crofts: New York.

Potter, M. C. (1976). Short-term conceptual memory for pictures. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 509-522.

Shepard, R. N. (1967). Recognition memory for words, sentences, and pictures. *Journal of Verbal Learning and Verbal Behavior, 6*, 156-163.

Standing, L., Conezio, J., & Haber, R. N. (1970). Perception and memory for pictures: Single trial learning of 2,560 visual stimuli. *Psychonomic Science, 19*, 73-74.

Yarbus, A. L. (1967). *Eye Movements and Vision*. New York: Plenum Press.