



False Memory 1/20th Of A Second Later: What The Early Onset Of Boundary Extension Reveals About Perception

By: Helene Intraub and **Christopher A. Dickinson**

Abstract

Errors of commission are thought to be caused by heavy memory loads, confusing information, lengthy retention intervals, or some combination of these factors. We report false memory beyond the boundaries of a view, boundary extension, after less than 1/20th of a second. Photographs of scenes were interrupted by a 42-ms or 250-ms mask, 250 ms into viewing, before reappearing or being replaced with a different view (Experiment 1). Postinterruption photographs that were unchanged were rated as closer up than the original views; when the photographs were changed, the same pair of closer-up and wider-angle views was rated as more similar when the closer view was first, rather than second. Thus, observers remembered preinterruption views with extended boundaries. Results were replicated when the interruption included a saccade (Experiment 2). The brevity of these interruptions has implications for visual scanning; it also challenges the traditional distinction between perception and memory. We offer an alternative conceptualization that shows how source monitoring can explain false memory after an interruption briefer than an eyeblink.

Intraub, H., & **Dickinson, C. A.** (2008). False Memory 1/20th of a Second Later: What the Early Onset of Boundary Extension Reveals About Perception. *Psychological Science*, 19(10), 1007–1014. <https://doi.org/10.1111/j.1467-9280.2008.02192.x>. Publisher version of record available at: <https://journals.sagepub.com/doi/full/10.1111/j.1467-9280.2008.02192.x>

Research Article

False Memory 1/20th of a Second Later

What the Early Onset of Boundary Extension Reveals About Perception

Helene Intraub and Christopher A. Dickinson

University of Delaware

ABSTRACT—*Errors of commission are thought to be caused by heavy memory loads, confusing information, lengthy retention intervals, or some combination of these factors. We report false memory beyond the boundaries of a view, boundary extension, after less than 1/20th of a second. Photographs of scenes were interrupted by a 42-ms or 250-ms mask, 250 ms into viewing, before reappearing or being replaced with a different view (Experiment 1). Postinterruption photographs that were unchanged were rated as closer up than the original views; when the photographs were changed, the same pair of closer-up and wider-angle views was rated as more similar when the closer view was first, rather than second. Thus, observers remembered preinterruption views with extended boundaries. Results were replicated when the interruption included a saccade (Experiment 2). The brevity of these interruptions has implications for visual scanning; it also challenges the traditional distinction between perception and memory. We offer an alternative conceptualization that shows how source monitoring can explain false memory after an interruption briefer than an eyeblink.*

Memory failure often involves errors of *omission*, but sometimes involves errors of *commission*, in which one falsely remembers details, words, or events that were not actually experienced. Errors of commission are generally associated with the presentation of confusing information (e.g., the *misinformation effect*; Loftus, Miller, & Burns, 1978) or with heavy memory loads

Address correspondence to Helene Intraub, Department of Psychology, University of Delaware, Newark, DE 19716, e-mail: intraub@udel.edu, or to Christopher Dickinson, Department of Psychology, Appalachian State University, Boone, NC 28608, e-mail: dickinsonca@appstate.edu.

and the passage of time (Bartlett, 1932; Koriat, Goldsmith, & Pansky, 2000). It is generally accepted that as memory fades, representations become less veridical and increasingly prone to biases based on preexisting knowledge. In some cases, however, errors of commission have been found to occur very rapidly. One such example comes from research on *boundary extension* (Intraub, Gottesman, Willey, & Zuk, 1996).

Boundary extension is a constructive error in scene representation; observers remember having seen beyond the edges of a view. Figure 1 shows examples of participants' drawings from memory of a multiobject scene (left) and a simple, single-object scene (right). In both cases, the remembered representation "overflowed" the physical boundaries of the view, anticipating upcoming layout in the world. Boundary extension is specifically related to memory for views of scenes. It does not occur when an object is presented without a scenic structure (e.g., objects on blank backgrounds; Gottesman & Intraub, 2002; Intraub, Gottesman, & Bills, 1998). It is associated with selective neuronal responses in brain areas related to scene representation: the parahippocampal place area and retrosplenial cortex (Park, Intraub, Yi, Widders, & Chun, 2007). It has been observed across the life span: in children and adults (ages 6–87 years; Seamon, Schlegel, Hiester, Landau, & Blumenthal, 2002) and in infants (ages 3–4 months; Quinn & Intraub, 2007).

Although most research on boundary extension has focused on relatively long-term memory (as in the examples in Fig. 1), a few studies have tested very short-term retention. In a rapid serial visual presentation (RSVP) paradigm, boundary extension occurred when the retention interval was as brief as 1 s (Bertamini, Jones, Spooner, & Hecht, 2005; Intraub et al., 1996). In response to the rapidity with which this error occurs, Roediger (1996) proposed that although boundary extension is evident after the picture is gone (i.e., in memory), it may actually take place while the picture is being processed and understood (in some sense

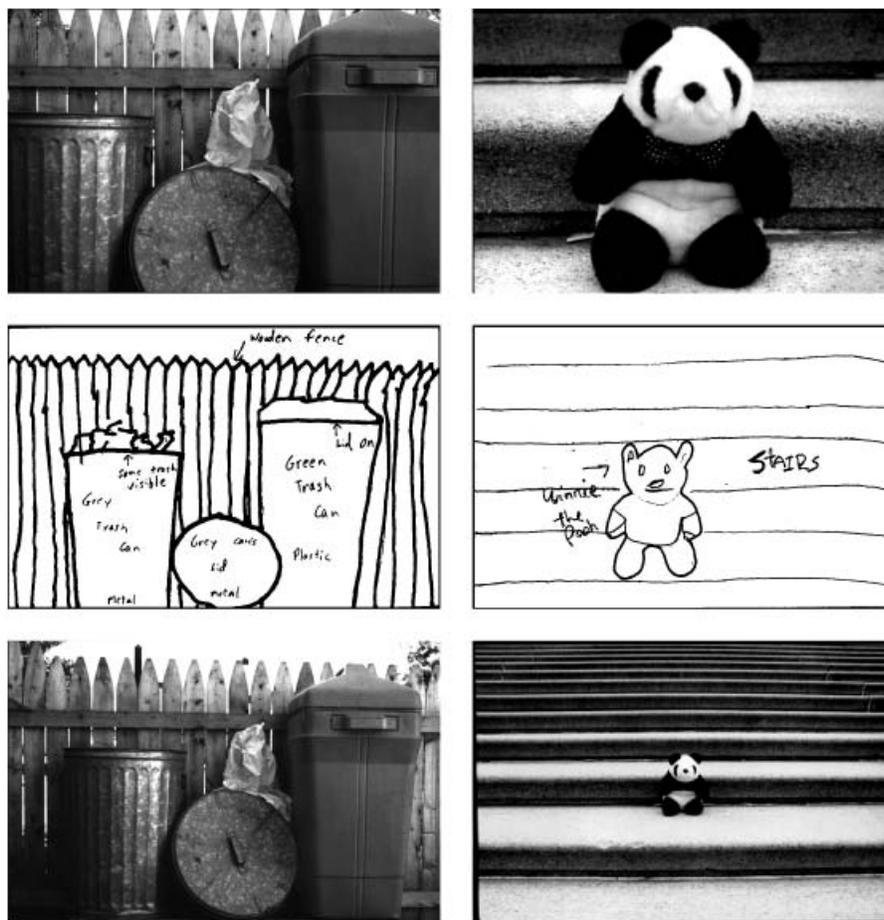


Fig. 1. Examples of boundary extension from previous experiments: close-up views (top row), participants' drawings of these views from memory (middle row), and wide-angle views of the same scenes (bottom row). Note that boundary extension (remembering layout beyond the given view) occurred both for multiobject scenes in which the main objects were cropped by view boundaries (as shown on the left) and for single-object scenes with no cropping of the object (as shown on the right); observers simply remembered seeing more of the world than was shown. (The illustrations on the left are based on Intraub & Richardson, 1989, Fig. 1; the illustrations on the right are based on Intraub, Gottesman, Willey, & Zuk, 1996, Fig. 1.)

perceived), thus falling at a point not clearly defined as either perception or memory. This contention is an important one, but, although a 1-s retention interval is surprisingly brief for a constructive memory error, it is a fairly long interval given the rapidity of scene comprehension, which is thought to occur within 150 ms or less (Potter, 1976; Thorpe, Fize, & Marlot, 1996).

What if memory for a scene were disrupted not for 1 s, but for the fleeting duration of an eye movement (a saccade)—on the order of 30 to 50 ms (Rayner, 1998)? Although it seems unlikely that computation of extrapolated layout beyond the boundaries could occur this quickly, if it did, it would raise important questions about the nature of scene representation during visual scanning, and the potentially adaptive role such errors might play. This brings us back to Roediger's (1996) point about the perception-memory divide, because it is important to recognize that visual scanning itself defies ready placement on either side of this theoretical boundary. This is because one can never see

the surrounding world all at once and must sample it through movements of the head and eyes. In so doing, one is forced to toggle back and forth between the visuo-sensory input and memory because each eye fixation is followed by a saccade during which vision is suppressed until onset of the next fixation (Volkman, 1986). For the fleeting duration of that saccade, the visual system must rely on memory: a short-lived transsaccadic memory (Irwin, 1991, 1993) and a long-term representation that accrues information across fixations (Hollingworth & Henderson, 2002). Might boundary extension (a constructive memory error) occur rapidly enough to be available in transsaccadic memory?

THE PRESENT STUDY

In the experiments reported here, on each trial a single view of a new scene was presented for 250 ms (a "fixation's worth"). This

view was then briefly disrupted before either the identical view or a slightly different view (a more close-up or a wider-angle view) appeared at test. In Experiment 1, the disruption (caused by the onset of a mask) lasted for the duration of a saccade (42 ms) or for a longer duration that approximated the time from the onset of one fixation to the onset of the next (250 ms); our goal was to determine if memory in either case would be prone to boundary extension. In Experiment 2, the disruption included an actual saccade. Observers used a 5-point scale to rate the test view as being “the same” as, “more close up” than, or “more wide angle” than the original stimulus. There were four trial types, defined by the combination of stimulus and test views: close-up stimulus, close-up test picture (CC); wide-angle stimulus, wide-angle test picture (WW); close-up stimulus, wide-angle test picture (CW); and wide-angle stimulus, close-up test picture (WC).

Surely one would expect observers to recognize the same view when the briefer (42-ms) mask was used, because in this case the disruption lasted less than 1/20th of a second. In physiological terms, such an interruption amounts to less than one eighth of the time taken by a spontaneous eyeblink (VanderWerf, Brassinga, Reits, Aramideh, & de Visser, 2003). However, if boundary extension “intervened,” the errors that occurred would follow a specific diagnostic pattern:

1. *Identical close-up views (CC)*: When stimulus and test pictures are identical close-up views, the test picture should be rated as more “close up” than the stimulus, which would indicate that the original view is remembered with extended boundaries.
2. *Identical close-up views (CC) versus identical wider-angle views (WW)*: Identical close-up views tend to yield more boundary extension than identical wider-angle views. In fact, wider views often yield little or no directional error (Intraub, Bender, & Mangels, 1992; also see Bertamini et al., 2005).
3. *Different views (CW and WC)*: When stimulus and test views do not match, a rating asymmetry should be observed. Boundary extension for the stimulus on CW trials would result in a mental representation that closely approximates the test item. In contrast, any extension of the stimulus on WC trials would exaggerate the difference between the stimulus and test views. Thus, the same pair of close and wider views should be rated as more similar on CW than on WC trials.

EXPERIMENT 1

Method

Stimuli and Apparatus

Two versions of 36 digital photographs of people, animals, and landscapes were created. Background complexity ranged from fields of grass to audience-filled bleachers. Close-up versions

were made by enlarging wider-angle views 8% to 21% and cropping the pictures to their original size (using Adobe Photoshop). Thus, the views within a given pair were the same size, but the wider view revealed more of the background, and the objects covered less area (see Fig. 2).

Stimuli were presented on a 21-in. flat-screen CRT monitor (32-bit color, resolution of 1024×768 pixels) run by a Pentium-based PC (Microsoft Windows XP operating system, 128 megabytes of video memory). Software written in C was based on an SR Research Ltd. (Mississauga, Ontario, Canada) template program and used Simple DirectMedia Layer (SDL; <http://www.libsdl.org>). Viewing distance was approximately 80 cm. Aspect ratios varied across the scenes; on average, pictures subtended $9.2^\circ \times 10.2^\circ$ of visual angle (widths ranged from 5.9° to 13.7° ; heights ranged from 8.9° to 10.4°).

Participants and Procedure

Seventy-two University of Delaware undergraduates (42 female, 30 male) participating in the general-psychology subject pool were randomly assigned to either the 42-ms-mask or the 250-ms-mask condition. All four trial types (CC, WW, WC, and CW) were randomly intermixed in each condition, with the constraint that no more than three trials of the same type could appear in a row.

On each of the 36 trials, participants fixated a yellow cross, which was followed by the stimulus (either the close-up or the wider-angle version of one scene). The stimulus was presented for 250 ms before being replaced by a mask (for 42 or 250 ms,

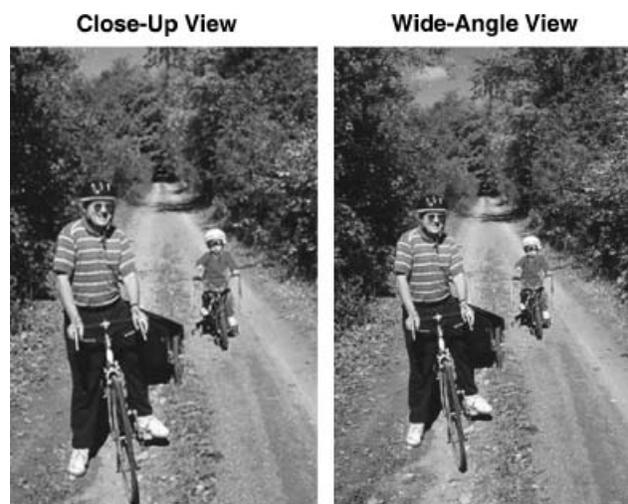


Fig. 2. A sample pair of stimuli. Note that when these pictures are side by side, as in this figure, the differences between the pictures may not be salient. However, if the pictures are shown in succession in the same spatial location with no mask (so that motion effects are allowed), the difference between them is highly salient; the wider-angle view reveals more of the scene, and the area of the main object decreases by 27.6% in that view relative to the close-up view. This image was taken from the Big Box of Art 615,000 Images database, Hemera Technologies (Gatineau, Quebec, Canada), and is in the public domain.

depending on the condition). The mask was dynamic (a black-and-white pattern mask with a $5.5^\circ \times 5.5^\circ$ circular “face,” similar to a “happy face,” that appeared in the center and changed every 150 ms; see Dickinson & Intraub, 2008). Thus, one central face appeared in the 42-ms condition, and two faces appeared in the 250-ms condition. This dynamic mask was intended to enhance maintenance of central fixation and to prevent participants from verbally describing the locations of the picture boundaries. The test picture (identical or alternate view) immediately followed the mask and remained on the screen until participants rated it relative to the stimulus. Response options were as follows: The camera’s position was “much closer up (–2),” “a little closer up (–1),” “the same (0),” “a little farther away (1),” or “much farther away (2).” Participants then entered a confidence rating: “sure (3),” “pretty sure (2),” or “not sure (1).” On 2% of the 42-ms trials and 0% of the 250-ms trials, observers selected a “missed the picture” option (e.g., because of blinking) in lieu of the confidence rating; these trials were excluded from analysis. The experiment always began with 2 practice trials.

Results and Discussion

Boundary extension occurred for both the 250-ms and the 42-ms retention intervals. All three rating patterns diagnostic of boundary extension were obtained, and ratings fell within the range observed in prior experiments using the same rating scale (e.g., Dickinson & Intraub, 2008). Figure 3 shows the mean rating for each trial type at each retention interval. As the figure

shows, CC trials yielded significant boundary extension ($d = 0.96$ and $d = 0.78$ in the 42-ms and 250-ms CC conditions, respectively), and WW trials yielded little or none (depending on condition). As in prior research, boundary extension on CC trials could not be attributed to extreme boundary-extension errors for a small subset of the pictures; 78% of the pictures on CC trials received mean ratings consistent with boundary extension. A 2 (retention interval: 42 ms, 250 ms) \times 2 (trial type: CC, WW) analysis of variance (ANOVA) revealed greater boundary extension on CC trials than on WW trials, $F(1, 70) = 16.32, p < .001, \eta_p^2 = .19$; no effect of retention interval, $F(1, 70) = 2.10, p = .15$; and no interaction, $F < 1$.

Observers were clearly on task. As Figure 3 shows, they were able to recognize CW and WC trials, correctly rating the test items as being more close-up or more wide-angle than the stimulus pictures. The mean ratings, however, revealed the critical asymmetry diagnostic of boundary extension. The difference between the mean rating and 0 (“same”) was smaller on CW trials than on WC trials. A 2 (retention interval: 42 ms, 250 ms) \times 2 (trial type: CW, WC) ANOVA showed that the absolute values of the mean ratings differed significantly between the two trial types, $F(1, 70) = 65.17, p < .001, \eta_p^2 = .48$ (main effect of trial type); there was no effect of retention interval, $F(1, 70) = 1.84, p = .18$, and no interaction, $F < 1$.

Overall, responses to repeated views showed that a 42-ms interruption of sensory input not only resulted in boundary extension, but also led to mean boundary scores that were similar to those obtained after a much longer (250-ms) interruption. Mean confidence ratings for the two conditions

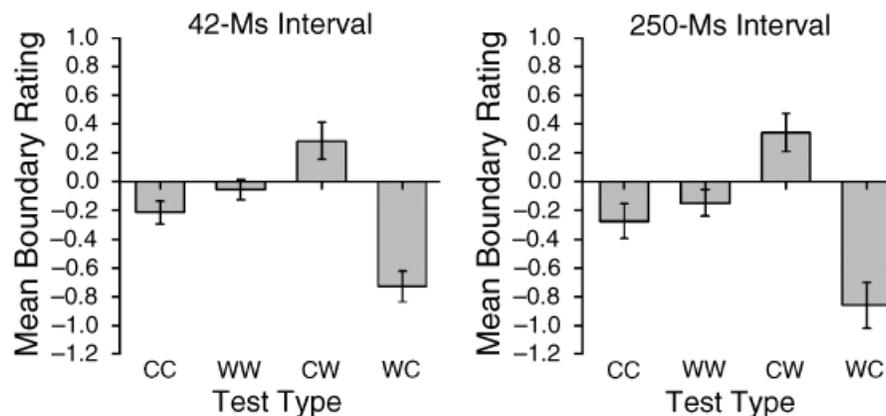


Fig. 3. Mean boundary ratings for each trial type in the 42-ms and 250-ms conditions of Experiment 1. Error bars show the 95% confidence interval around each mean. The four trial types are defined by the combination of stimulus and test pictures: close-up stimulus, close-up test picture (CC); wide-angle stimulus, wide-angle test picture (WW); close-up stimulus, wide-angle test picture (CW); and wide-angle stimulus, close-up test picture (WC). The rating scale ranged from –2, which indicated that the test picture was “much closer up” than the stimulus picture, to +2, which indicated that the test picture was “much farther away” than the stimulus picture. A rating of 0 indicated the stimulus and test picture looked “the same.” On CC and WW trials, a negative mean rating significantly less than 0 (i.e., 0 falls outside the confidence interval) indicates boundary extension; on CW and WC trials, a mean rating that differs significantly from 0 indicates that observers correctly recognized that the pictures differed. Asymmetric mean ratings on CW and WC trials (CW mean ratings closer to 0) also indicate boundary extension.

both centered on “pretty sure” and did not differ (1.98 vs. 2.08 for the 42-ms vs. 250-ms conditions, respectively), $t(70) = 1.22$, $p = .22$.

These results were surprising. Although observers knew precisely what would be tested on each trial, and were required simply to maintain fixation, a disruption lasting less than 1/20th of a second was sufficient for boundary extension to occur. Next, we asked if the same outcome would hold if an actual saccade was made between the first and second presentations of the scene.

EXPERIMENT 2

In Experiment 1, although the 42-ms condition mimicked a saccade, the task demands were minimal relative to those required by an actual eye movement. In Experiment 2, stimulus and test locations were on different sides of the screen, requiring a saccade, and the test picture did not appear until the eyes moved into the test region. Thus, the stimulus had to be maintained in memory while attention shifted rapidly to the new location (e.g., Hoffman & Subramaniam, 1995; Kowler, Anderson, Doshier, & Blaser, 1995) and an eye movement was planned and executed. If these greater demands compromise a presumably fragile transsaccadic memory, then observers might make random errors, instead of exhibiting boundary extension. This would be evidence against the existence of boundary extension during visual scanning, suggesting instead that it rapidly occurs only under the extremely simplified conditions used in Experiment 1. In contrast, replication of Experiment 1 would indicate that the transsaccadic representation can include boundary extension, and thus that this anticipatory spatial representation is available to play a role in the integration of successive views.

Method

Participants

Thirty-two undergraduate volunteers (21 female, 11 male) from the same population as in Experiment 1 participated.

Stimuli and Procedure

The stimuli and procedure were the same as in Experiment 1 except that (a) stimuli appeared on one side of the screen and test pictures on the other, requiring a gaze shift (for half the participants, the stimulus was on the left; for the others, it was on the right); (b) the dynamic portion of the mask appeared in the center of the test region (serving as the saccade target); and (c) the test picture appeared when the participant's eyes crossed into the test region. Thus, the test picture was present when the eyes landed. The center-to-center distance between stimulus and test pictures ranged from 8.4° to 14.2° ($M = 11.8^\circ$). Test procedures were the same as in Experiment 1. Trials on which participants executed more than a single saccade were excluded from analysis (39% of all trials).

Apparatus

The apparatus was unchanged except for the addition of an EyeLink II head-mounted video eye-tracking system (SR Research Ltd., Mississauga, Ontario, Canada) that was used to monitor eye movements and control onset of the gaze-contingent test item. Eye position was sampled at 500 Hz, the system's spatial resolution was estimated to be less than 0.4° , and head position and viewing distance were fixed with a chin rest.

Results and Discussion

Boundary extension occurred; all three diagnostic rating patterns were obtained. Figure 4 shows the mean rating for each trial type. As the figure shows, the CC condition yielded boundary extension ($d = 0.85$), and the WW condition yielded no directional error; mean ratings were greater on CC trials than on WW trials, $t(31) = 2.49$, $p = .018$, $d = 0.56$. Again, the mean CC rating reflected a boundary-extension error for a majority of the pictures (64%). On WC and CW trials, participants correctly detected the change, but as before, their mean ratings revealed the critical asymmetry diagnostic of boundary extension;

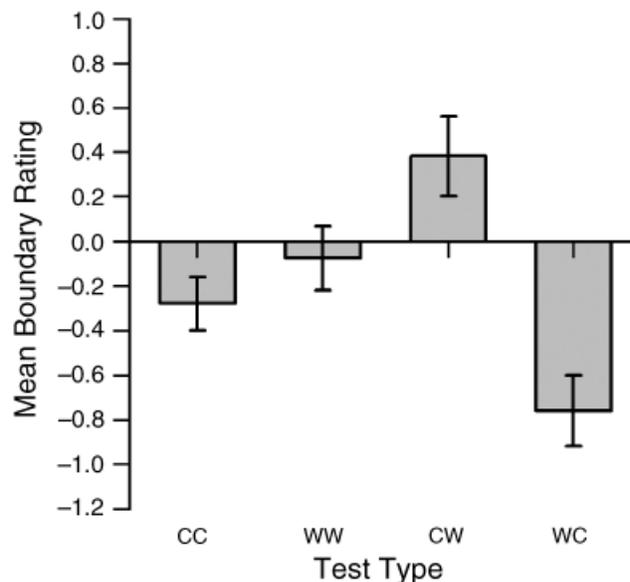


Fig. 4. Mean boundary rating for each trial type following a single saccade between stimulus and test (Experiment 2). Error bars show the 95% confidence interval around each mean. The four trial types are defined by the combination of stimulus and test pictures: close-up stimulus, close-up test picture (CC); wide-angle stimulus, wide-angle test picture (WW); close-up stimulus, wide-angle test picture (CW); and wide-angle stimulus, close-up test picture (WC). The rating scale ranged from -2 , which indicated that the test picture was “much closer up” than the stimulus picture, to $+2$, which indicated that the test picture was “much farther away” than the stimulus picture. A rating of 0 indicated the stimulus and test picture looked “the same.” On CC and WW trials, a negative mean rating significantly less than 0 (i.e., 0 falls outside the confidence interval) indicates boundary extension; on CW and WC trials, a mean rating that differs significantly from 0 indicates that observers correctly recognized that the pictures differed. Asymmetric mean ratings on CW and WC trials (CW mean ratings closer to 0) also indicate boundary extension.

deviation from 0 (“same”) was significantly smaller for CW than for WC trials, $t(31) = 2.87$, $p = .007$, $d = 0.80$. The mean confidence rating across trials was 2.1 (“pretty sure”).

Eye movement data showed that observers followed instructions and rapidly shifted their gaze to the test area following stimulus offset. Mean saccade latency (from stimulus offset) was 258 ms, and mean saccade duration was 54 ms; thus, the retention interval was, on average, 312 ms. Although disruption by a mask and a saccade provided a more demanding situation than in Experiment 1, robust boundary extension occurred.

GENERAL DISCUSSION

Boundary extension, an error of commission, occurs extraordinarily rapidly. Observers remembered having seen the continuation of the view beyond its physical boundaries when the sensory input was disrupted for less than 1/20th of a second! They remembered having seen more of the scene than was shown. The rapid onset of this false-memory effect has implications for theories of scene perception. In addition, it challenges the traditionally held division between perception and memory. We discuss each topic in turn.

Scene Representation

These experiments show that scene representation is already extended by the time the observer compares one view with the next. Experiment 1 showed that when a single view of a scene was interrupted by a mask for a fleeting duration equal to the duration of a saccade (42-ms-mask condition), although the view had not changed, participants thought it showed less of the scene than before (i.e., a more close-up view). Conditions in which the closer version was followed by the wider-angle version or vice versa yielded the critical response asymmetry diagnostic of boundary extension, thus supporting the same conclusion. Experiment 2 showed that the boundary-extended representation was robust enough to survive a shift in spatial attention and the implementation of a saccade.

Because memory had to be tested immediately following a single fixation, none of the conditions could include free viewing. Is it plausible that boundary extension might occur on-line during visual scanning? We suggest that it is because these experiments “bracket” the normal viewing situation. Experiment 1 was less demanding because observers simply had to maintain their gaze and attend to a single location on each trial; Experiment 2 was more demanding because observers had to consciously shift their gaze to a new location in response to a cue while holding the first view in memory. Yet robust boundary extension occurred in both cases. Further support comes from other research in which comparable results were obtained when we embedded the stimulus in an RSVP sequence, thus capturing some of the dynamic changes inherent in visual scanning (Dickinson & Intraub, 2008).

We argue that rather than being disruptive, boundary errors during visual scanning are more likely to have a positive impact on scene perception. This is because the “goal” of the system is to provide a coherent representation of the world—not a record of the spurious boundaries of each individual view. Anticipatory representation of the continuation of layout beyond view boundaries may serve to “fill in” gaps during scanning, and perhaps prime soon-to-be-visible layout (Sanocki, 2003). Thus, boundary extension could serve to facilitate integration of successive views into a coherent representation (Intraub, 1997). The surprising rapidity of the error, however, poses a challenge for the traditionally held division between perception and memory.

Perception Versus Memory

The traditional information-processing approach to perception begins with a representation of the stimulus. If there is no mask, a veridical sensory representation may be briefly maintained in a sensory register (Sperling, 1960); otherwise, aspects of the (previously veridical) representation will be directly processed in one or more very short-lived memory stores (e.g., transsaccadic memory—Irwin, 1991, 1993; conceptual short-term store—Potter, 1976; visual short-term memory—Phillips, 1974). Memory in these stores is not “picture perfect.” Indeed, considerable research has focused on the paucity of the representation during this time (e.g., *change blindness*; Simons & Rensink, 2005). If attention is maintained, however, ultimately these briefly stored aspects of the view will be consolidated in long-term memory.

At what point in this process would boundary extension take place? Given this framework, we would have to postulate that it would begin after the (veridical) sensory input is gone, but be completed rapidly enough to influence assessment of the next view. Considering that the briefest interruption in Experiments 1 and 2 was a mask lasting only 42 ms, the processes responsible for boundary extension would have to rapidly unfold in one of these early buffers. Perhaps this is what happens, but the timing seems prohibitively brief. Equally important, the cause of this boundary extension is left unspecified—an ad hoc “extrapolation process” must be invoked to explain it.

We offer an alternative conceptualization that we believe provides a more parsimonious account of rapid boundary extension. Whereas the traditional approach begins with a representation of the visual sensory information, consider instead the possibility that the ensuing perceptual representation is not derived from a single source (sensory input), but simultaneously draws on at least two other sources of input related to scene structure. Both are internally generated (i.e., top-down).

One of these additional sources of input is *amodal perception*, which is instituted in response to occlusion of the world at the view boundaries (Gottesman & Intraub, 2003). Amodal processes (thus named because they draw on no sensory modality)

“fill out” the occluded portions of objects (object completion; Kanizsa, 1979) and the continuity of surface textures (Kellman, Yin, & Shipley, 1998; Nakayama, He, & Shimojo, 1995). This is a critical aspect of everyday perception. The amodally generated layout beyond the view boundaries in our example would be a tightly constrained continuation of the visible content at the periphery of the view. The other source of information is purely spatial, carrying no specific information about the scene. This spatial framework would provide the observer with a sense of the space beyond the left, right, top, and bottom boundaries of the view (Attneave & Farrar, 1977; Franklin & Tversky, 1990). All views, after all, reveal only part of an otherwise continuous world.

Thus, we propose that scene perception has multiple sources: sensory, amodal, and spatial (and likely others, e.g., semantic knowledge). During the first fixation, while the stimulus is visible, mental representation would parallel the sensory input. Resolution would be highest at the point of fixation (foveal vision), decrease for information falling farther in the periphery, and decrease again for the amodal region; finally, at the point where only the general spatial framework is available, no further detail could be resolved without shifting gaze (or in a photograph, shifting the camera’s viewpoint).

The boundary error does not occur while the stimulus is present, because the difference between currently active sensory information in the periphery and top-down amodal information is readily discernible. However, when the sensory input is interrupted, this changes. The mental representation is available, but no longer has the contribution of a sensory source. There are no “tags” to specify the exact point at which peripheral information was originally derived via low-acuity peripheral vision or highly constrained amodal perception, although both provide a level of detail unavailable in the spatial structure falling beyond them. Thus, at test, when the observer must distinguish which portion of a multisource scene representation was “seen before” (i.e., derived from the visual sensory input alone), some of the information originally generated by amodal processing is misattributed to sensory perception, causing boundary extension.

In contrast to the traditional conceptualization, this account does not propose that the extended region is constructed after the view is gone (i.e., when the observer’s experience shifts from “veridical perception” to “faulty memory”). Instead, the extended region was already part of the representation (albeit, an amodally generated part) while the sensory input was available. Thus, there is no need to propose activation of an extrapolation process following stimulus offset. Instead, boundary extension is the result of a *source-monitoring* error (Johnson, Hashtroudi, & Lindsay, 1993)—specifically, a *reality-monitoring error* (Johnson & Raye, 1981), because the test requires the observer to distinguish between externally generated information (visual perception of the sensory input) and internally generated information (amodal perception just beyond the edges of the view).

A key insight expressed in the source-monitoring model is that the source of a memory is an attribution based on the amount and quality of details (perceptual, contextual, semantic, or emotional) in the representation (Johnson, 2006; Johnson et al., 1993). This model can explain highly detailed false memories (e.g., memories for events that one did not experience, but heard other people describe, or that were dreamed), as well as more mundane mental puzzles (“Did I actually turn off the stove before we left, or did I just think about it?”). For example, if memory for a dream includes highly specific perceptual details (a hallmark of memories based on sensory experience), one may err in attributing the source of the memory to perception. We propose that the same ideas are applicable to memory tested following an interruption briefer than an eyeblink, and can account for false memory beyond the boundaries of a view.

CONCLUSIONS

Boundary extension (an error of commission) occurs extremely rapidly; observers erred when sensory input was interrupted for less than 1/20th of a second. If one thinks of perception as incorporating information from multiple sources (sensory, amodal, and spatial) simultaneously, instead of drawing on the visual sensory input alone, one can then explain rapid boundary extension without appealing to an ad hoc extrapolation process. Instead, the same principles that underlie source monitoring in long-term memory can be applied to a situation in which one falsely remembers having seen more of a scene than was shown. The rapidity of this error would be advantageous rather than harmful, because the goal of the visual system is not to represent the spurious boundaries of each fleeting view, but to incorporate those views into a coherent, continuous representation of a surrounding world.

Acknowledgments—This research was supported by National Institutes of Health Grant RO1MH54688. We greatly thank Kari Schweifel and Jason Rand for their assistance and Jay Reiss for his comments on the manuscript.

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(RECEIVED 1/11/08; REVISION ACCEPTED 3/12/08)