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An Icon Can Have No Worth in the Real World: Comments on Loftus, Johnson, and Shimamura's "How Much Is an Icon Worth?"

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Loftus, Johnson, and Shimamura (1985) demonstrate a novel procedure by which they estimate the worth of an icon. My comment is not directed at the methodological implications of the procedure, but at the theoretical generalizations that are made about the worth of icons. Evidence for iconic storage is obtained only in paradigms in which a single, brief, discrete stimulus flash is presented to an eye that has been exposed to a blank homogeneous field both before and after the stimulus. Although such a paradigm has great value in the study of visual persistance, visual masking, and related phenomena, it bears no resemblance to the way in which stimuli are presented during typical sequences of looking behavior. Contrasting such probe experiments in the laboratory with normal perceiving in the natural world shows that the conditions that produce iconic-like persistence do not exist under naturalistic perceiving, and if we had iconic storage of the previous instant of stimulation, perceptual chaos rather than continuity would prevail. The icon exists only in a narrowly defined environment, in much the same way as do afterimages, motion aftereffects, and the like. It reveals the workings of basic processes in the visual system—a downward generalization, but does not require invention of higher level functions: the icon doesn't generalize upward.

Loftus, Johnson, and Shimamura (1985) suggest an interesting methodological procedure to estimate the time over which information can be extracted from an "icon" of a picture. They present very brief exposures of single pictures to dark-adapted subjects. In one condition a picture is presented for a duration of d milliseconds, followed by a visual noise mask, but sufficiently delayed so that a typical persistence would be expected to develop. Across four experiments, they use a number of d values, and for each, measure a different kind of perceptual performance about the pictures (old/new recognition, the number of details that could be described, or the confidence of subsequent recognizability). Thus, for each d value, which is expected to be followed by an icon, they have a level of performance. The authors then ask: If a picture is presented for d milliseconds, but without allowing any persistence to be added to the stimulus duration (using a mask that immediately follows the offset of the picture), how much extra time (a) would have to be added to d so that the performance level at $d + a$ would be the same as the performance at d when there is an icon present? By determining this value of a, they have an estimate of the effective worth of the icon. Loftus et al.'s principal finding is that a turns out to be about 100 ms for each of the three response measures used. It also is invariant over the different values of d used, and in one experiment, over two values of luminance used. From this, Loftus et al. conclude that an iconic storage of information following the offset of a brief flash of a stimulus is equivalent to the extension of the stimulus itself. Because the amount of that equivalent extension is the same, regardless of the variations in procedures they tried, they further conclude that "an icon's worth would be a constant of the perceptual system (1985, p. 11)."

This is a novel procedure that appears to provide a new way to estimate the usefulness of poststimulus persistence. But what Loftus et al. forget is that their work, and especially their conclusions, is limited by their experimental conditions and seems unlikely to apply to "*the* perceptual system" (emphasis added) as it is found outside of the laboratory. Iconic storage mechanisms have no relevance to any perceptual theory concerned with typical perceptual behavior.

To document this argument, I contrast visual information gathering as it is studied when iconic processes are being investigated in the laboratory with the way it typically occurs under normal viewing conditions and tasks. From that comparison, I show that none of the properties ascribed

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to iconic storage apply to normal perception. Finally, I briefly examine the various proposals suggested for the "necessity" of iconic storage to solve a variety of theoretical problems in visual perception, showing in each case that trying to drag a persistence-like icon out of the laboratory hinders rather than advances our understanding of visual perception.

The Viewing Task Needed to Study Iconic Processes

All experiments on iconic memory since the time of Sperling's (1960) first report and all those previously reported that have been reinterpreted into iconic concepts follow the same basic procedure. The subject fixates a blank screen (sometimes with a fixation point added), onto which is presented a brief flash of an informational display. Following the termination of the flashed picture, the screen returns to its previous state. Sometimes the screen is dark before and after the flash, sometimes illuminated at the same or at a different intensity as the picture. (Sometimes a brief masking flash is also presented after the termination of the picture, this being done to attenuate or eliminate poststimulus persistence or iconic storage—a control procedure.) Whatever the variations, the basic paradigm is a blank screen—flash—blank screen viewing arrangement, in which the subject has no patterned stimulation before or after the briefly flashed picture is presented. The picture to be perceived is temporally and spatially isolated from all other stimulation.

There is now overwhelming evidence that activity in the early stages of visual processing persists under specific, reasonably well understood conditions. These conditions include a relatively briefly presented stimulus, preceded and followed by a homogeneous field, either lighted or dark. A half century of close attention to this phenomenon has uncovered most of its properties. This research has produced a wealth of psychophysical functions and a number of theoretical attempts to combine all of them into models of the how, where, and why of persistence. I reviewed some of the high-points of that work (Haber, 1983a, 1983b) and referred there to others who have done a more complete review and analysis. The research on visual persistence, in all of its forms, has made and is continuing to make major contributions to our understanding of basic visual functioning.

The methods used to study visual persistence overlap almost entirely with those to study iconic storage, sufficiently so that most information processing theorists simply assume that iconic storage results from some kind of persistence somewhere in the visual system.

Presentation Procedures Typical of Normal Viewing Tasks

Human beings spend virtually all of their waking time located in three-dimensional scenes, in which usually they, and often parts of the scene, are in motion. Consequently, the display before their two eyes is three-dimensional and continuous in time—its reflecting surfaces continue to reflect light toward the observer, irrespective of the observer's behavior. In addition, the light projected to the two eyes is always different, and the projections undergo continuous and global transformations during the motions of the observer. Human beings also spend some time looking at two-dimensional displays, as when they read, watch television or movies, or look at pictures. I will concentrate mainly on such two-dimensional displays in my argument because these displays have been the subject of perceptual theory. Further, as will be obvious, iconic processes are even less usable for understanding how we perceive three-dimensional scenes than two-dimensional displays, so if I can show their irrelevance to flat displays, I will have done enough.

When we look at a picture, typically the picture is fixed on the wall or screen or held in the hand, but it remains continuously visible during the course of looking—several seconds or more. The viewer's two eyes usually make a number of rapid saccadic movements during this time, as different parts of the picture are examined. Accommodative and vergence movements of the eyes occur if there is any variation in the depth of the picture (as when it seen from an angle) or when the gaze shifts from the picture to some other part of the scene. Head and body movements may also occur, some of which may provoke compensatory eye movements. Finally, drift movements of the two eyes occur, which are essentially failures to maintain a stable fixation of the eye between saccadic eye movements.

Most researchers who build iconic storage models concentrate on the saccadic components of this viewing process and ignore the others. In typical picture (and scene) looking, a number of separate fixations are made by the viewer, each from 250 ms to several thousand milliseconds in duration, with very rapid saccadic eye movements between each one. Such theorists apparently assume that the onset and offset of the fixation period between each saccade constitutes a time unit during which a single, stable pattern occurs on the retina, in a single stable location. They then propose that some kind of iconic store is needed or is useful in the processing of each of those separate fixed images.

But there are no separable different retinal images that can be isolated by their fixed locations on the retina for fixed durations. Superimposed on those saccadic generated fixations are continuous drifts of the eye's position during each fixation (see Steinman & Collewijn, 1980, for powerful demonstrations of the ubiquitousness of drifts). These often exceed 15 min in magnitude, more than enough to dramatically overlap vastly different contents of the image of the picture *within* the time frame of a single fixation. Voluntary head and body movements, often made as an aid in the looking process, also produce continuous displacements of the picture image that are superimposed on the timing of the saccadic movements. Although such body motions may be under some of the same attentional processes that control the pattern of saccades and fixations, additional body motion is nearly always present as a result of sway, and especially during locomotion as when walking. It is unlikely that the control and timing of such body motions, and therefore their resultant effects on retinal image motion over the retinal surface, are coordinated at all with the saccadic movements concerned with looking at the picture. Further, while head and body motion inevitably causes lateral translation of retinal images over the retina, the resulting motion perspective dramatically changes the relative positions of the objects represented in the image, as well as the overall scale of the image. From such body motions, there are continuous changes in the retinal images, not just translations of the same image to a new location over the retinal surface. Finally, if there is variation in depth in the scene or picture, then accommodative and vergence eye movements are likely. Not only do these change the overlap between the images to the two eyes (and iconic theories seem always to forget that we have two different ones), but they change the parts of the projected image that are focused for maximal depth of field.

In short, the retinal image of any freely viewed picture or scene is always in flux vis-à-vis the retinal surface and is never fixed in a particular retinal location. The image usually changes in its pattern from moment to moment, as a result of head and body movements, as well as makes accommodative changes. Finally, we have two images, not one, and except in highly contrived settings, the two never match each other pictorially. Most theorists have been misled into thinking of separable stable fixations because of inappropriate generalizations from laboratory research where it is possible to fix a stable retinal image on a stable retinal surface by limiting exposure duration, eye and head motion, and task complexity. Stable, unchanging, and fixed retinal images are not typical of free viewing and rarely occur.

There is nothing in the methodology used by Loftus et al. that resembles normal picture looking. Not even looking at pictures by lightning flashes is as bizarre as what they do. By what generality do Loftus et al. propose to extend their findings to free viewing of pictures or to any other imaginable circumstances of looking at pictures or scenes? Their work has nothing to do with the perception of pictures, except in the highly artificial, contrived, and ungeneralizable conditions they used in their laboratory.

Where Could the Icon Possibly Fit Into the Sequence of Events During Normal Viewing?

Given the way in which an active viewer interacts with a typical picture (or scene), what function could some additional persistence of the stimulus picture have? How might an extension of 100 ms of the presentation duration help in the process of perceiving the picture?

The problem in answering these questions is the impossibility of defining *stimulus duration* in the context of free viewing. There is no duration of the stimulus in the sense of onset and offset of stimulation of the eye, unless that is taken to be many seconds long, the offset typically corresponding to when the viewer turns away to look in some other direction. Certainly, it is not at the end of such a long viewing time that an added iconic persistence could be considered useful to visual processing.

For these reasons, I find it most difficult to imagine how to take advantage of any kind of persistence of stimulation of the form described by Loftus et al., in which additional information is extracted from an icon equivalent to an extension of the stimulus duration by $\frac{1}{10}$ s. Which part of which moment of stimulation is to be preserved for the equivalent of 100 ms of extra exposure? Where do we insert this 100 ms of extra iconic storage? Putting it after the last of the glances, when the gaze shifts to an entirely new picture, blank wall, or the view out the window, typically after thousands of milliseconds of viewing, would not add very much (if anything) to the overall processing capabilities. The last one of a long sequence of fixations is no more informative than are earlier ones, and results by Mackworth and Morandi (1967) and Loftus and Bell (1975) suggest that the early ones are likely to be the more informative.

An alternative place where the iconic storage might be useful is during each actual saccade, to bridge the 25–50 ms of saccadic movement time. Proponents of this alternative (see the commentaries on Haber, 1983a, for details of this proposal) suggest that because sensitivity is attenuated during the saccade, and for some milliseconds before and after the actual motion, a persisting image of the stimulus would help explain the continuity of perception during this "interruption" of stimulation. As with the notion of a fixed retinal image, this alternative fails to consider the nature of the sequence of images that typically occur. When the eye moves saccadically over a picture or scene, the retinal image of the presaccadic fixation and the one from the postsaccadic fixation are not the same—at a minimum, they differ in registration by the amount of the movement and usually also differ in their pattern as well. If the icon preserves the presaccadic image for some extra time, that simply brings the two differing images into closer temporal proximity, without in any way reducing their differences. As long as the icon is treated as equivalent to extended physical duration of the stimulus (as it is by Loftus et al. and most other icon theorists), preserving the stimulus during saccades would produce greater interference, not more continuity. Of course, when the two successive images differ by more than just registration, chaos is ensured if either of them is preserved for extra time.

A similar suggestion has been made about the use of the icon to provide continuity during eye blinks. Most human beings do not notice the perceptual interruption during the physical closure of the eyes, and when asked to attend to such interruptions, dramatically underestimate their duration (Riggs, Volkmann, & Moore, 1981). But eye blinks are superimposed randomly on all of the other movements of the eyes, head, body, and environment that occur. The probability that the pattern of retinal stimulation just preceding a blink matches the pattern just after a blink is very small (except in the laboratory with a fixed stimulus, a brief stimulus, and a fixed head). What, then, would be the advantage of preserving the preblink pattern, if it is juxtaposed more closely in time with a different one?

I have considered two proposals for where to use the icon to help with the perception of pictures or scenes, one after the eyes finish examining a picture and another during saccades and blinks. Neither of these alternatives makes any sense as a method to extend viewing time. I could consider other ones, but all of those suggested suffer the same deficiencies in the context of typical picture and scene looking.

Examples of Inappropriate Theoretical Uses of an Iconic Mechanism

Theorists have suggested, and in some cases elaborated a number of exemplars of possible functions of an icon (see Haber, 1983a, 1983b, especially the 30 commentators on 1983a; also see Hochberg, 1968; Turvey, 1977). Some of these suggestions stem from genuine commitment to belief in an iconic process, while others have simply accepted an icon as an early stage of information processing and looked around for problems that might be solved by a persistence-like process. I have already discussed proposals for bridging the gap between fixations left by the saccadic movement and by eye blinks. Neither of these "problems" gains anything by appealing to iconic storage of the immediately prior presaccadic or preblink retinal stimulation.

The icon has been suggested as a mechanism for providing integration of perception across saccadic eye movements, so that the different retinal images can be put together into a panoramic view of the picture or scene, larger than what was seen during any one of the separate fixations made while looking at it. According to some theorists, perception requires that the succession of retinal images has to be "realigned" or matched to each other in a kind of template process, so that we can perceive the stimulus picture as the same, regardless of where our eyes happen to fall on it. But, as already shown, there is no succession of retinal images that differs only in registration, so there is no image that can be first stored and then matched to another image. There are no discrete retinal images at all—just a continuously changing pattern of stimulation. I can see no place for an iconic storage process here. If we add the fact that what we "see" can be neither of our retinal images, but some kind of cyclopean representation that takes the differences between the information coming to the two retinas into account, an icon of either retinal image seems quite out of place. I think the entire "integration" problem is misstated because of the false assumptions about the discrete nature of retinal images as fixed pictures.

The icon has also been suggested as a necessary mechanism to account for apparent motion effects. Some theorists have assumed that the perceived smooth motion arising from discrete successive presentations requires some kind of persistence mechanism to store each of those successive displays. Again, careful analysis shows that increasing the effective duration of any of the separate presentations could not help account for the perception of motion, let alone smooth motion. In phi motion, for example, the evidence is clear: Apparent motion is eliminated if the duration of either stimulus is extended so that the time interval between the offset of one and the onset of the next is filled with the stimuli.

Iconic storage has also been proposed to account for the perception of motion picture (and video) sequences. Hochberg and Brooks (1978) have provided the most detailed analysis of the problems involved in explaining how we can perceive smooth motion, and especially the continuity of the scene, from a succession of static presentations. Their analysis makes clear that that succession is not simply a series of views that are identical except for their registration of the scene. We can easily see motion and scene continuity when the succession is generated by a camera moving laterally across the scene, or moving radially into the scene. Yet in both cases, motion perspective, object size, and scene scale each would change the pattern of stimulation from frame to frame. Seeing continuity can not be a process of using each frame as a template against which the next one has to be aligned. There is no template, at least not at the level of the film frame, or the projected light to the eye. Therefore, there can be no advantage of extending the effective duration of any frame vis-à-vis the next frame. No place here for an icon.

Finally, some theorists have simply argued that because we can easily demonstrate iconic storage under certain laboratory conditions, there must be a function for this persistence in more typical (nonlaboratory) perceptual tasks. Why else, such an argument goes, would there be persistence in the visual system unless it were useful. This argument is reductionism in reverse, and no more profitable. We have many examples of visual effects that can be demonstrated only under special conditions. The existence of these effects is informative of certain aspects of visual functioning but does not require that the effects themselves be built into higher order functioning. For example, under dark-adapted conditions we easily see afterimages following an intense flash. The study of such effects has revealed information about the time course of receptor action and, in some cases, about neural interactions in the retina. But we do not believe that afterimages are "used" for anything important or typical in normal perception. They occur only under rather atypical conditions. Similarily, motion aftereffects, such as the waterfall illusion, are easily demonstrated when looking at a blank field following prolonged examination of a moving pattern and have provided important evidence concerning the coding of information about motion. But the waterfall illusion itself is typically not a component of the processing of motion. Arguing that because iconic storage can be demonstrated in the laboratory and therefore must be a part of normal perception is equivalent to saying that afterimages or waterfall illusions are necessary components of normal perception too.

In sum, I can see no place for an icon anywhere in our accounts of perception. There is persistence in the visual system, but only in the blank screen—picture—blank screen presentation paradigm. The Loftus et al. evidence has nothing to do with the perception of pictures except for the highly artificial conditions they used in their laboratory. The fact that they used pictures as stimuli does not make this an experiment on picture perception. At best, this is an experiment on persistence, and if they had explored the implications of their results in that more appropriate context, especially their findings regarding the invariances, it might turn out to be an important one. But when there is a continuous visual world out in front of the eyes, stimulation is continuous and continuously changing. Adding any mechanism that stops that continuity by briefly inserting preserved bits of what just happened should create chaos in perceiving just as it does in our theories of perceiving.

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