Journal of Experimental Psychology:
Human Perception and Performance
1985, Vol. 11, No. 3, 379-383

0096-1523/85/$00.75

E Pluribus Unum: Rursus? A Comment on Loftus, Johnson, and Shimamura's "How Much Is an Icon Worth?"

Vincent Di Lollo
The University of Alberta, Edmonton, Alberta, Canada

Loftus, Johnson, and Shimamura (1975) displayed a test stimulus (a picture) followed by a masking stimulus either immediately or after a 300-ms delay. They attributed the superior performance obtained with the delayed mask to the continued availability of a visible icon. Here I suggest that Loftus et al.'s explanation is questionable on empirical and on conceptual grounds. Instead, I propose an account based on more traditional concepts of backward masking by pattern (e.g., Scheerer, 1973) and on nonvisible schematic representations of visual displays.

Not long ago, the impending demise of the icon was heralded (by Haber, 1983) among choruses of wails and cheers. But, it seems, old icons never die, although they might fade away.

In the present commentary, I refer to Loftus, Johnson, and Shimamura's (1985) article in which iconic memory is employed as the explanatory basis for a set of experimental findings. My aim is to question some aspects of Loftus et al.'s theoretical treatment and to suggest a simpler and more parsimonious explanation.

Loftus et al. (1985) accept the concept of the icon as a visible extension of a stimulus and set out to estimate the amount of information that can be extracted from icons produced by stimuli of different durations. Their experimental paradigm was relatively simple. Stimuli of varying durations were displayed under two conditions of masking: immediate mask (masking stimulus displayed immediately upon termination of the visual stimulus) and delayed mask (mask displayed 300 ms after termination of the stimulus).

As might be expected, Loftus et al. (1985) found a lawful relation between stimulus duration and severity of masking: As exposure duration was increased, the harmful effect of the mask was reduced. They also found that perception of the contents of the stimulus was superior if the mask was delayed. More important, they were able to quantify the effects of mask delay by matching levels of performance under the two masking conditions. The matches showed that, at all stimulus durations, delaying the mask was equivalent to exposing the stimulus for an extra 100 ms in the immediate-mask condition. For example, the same amount of information could be extracted from a 500-ms stimulus with a delayed mask as from a 600-ms stimulus with an immediate mask.

There are two plausible accounts of these findings: One ascribes the masking effects to interference with a visible icon; the other ascribes them to interference with processing events that vary as processing goes on but that are not necessarily visible. Below, I outline the former account, point out some of the difficulties that it encounters, and conclude that the latter is probably preferable.

An Iconic Account

Favored by Loftus et al. (1985), the iconic account assumes that a visible representation (icon) of the stimulus persists for some time after the external stimulus has terminated. As a basis for extraction of information, the icon is regarded as equivalent to the physical stimulus itself. As it were, the icon provides some additional exposure duration and, therefore, some added opportunities for extracting information from the stimulus. This is possible with a delayed mask (a condition that leaves the icon virtually undisturbed) but not with an immediate mask, which destroys the icon and, in so doing, denies any further opportunity for extraction of information.

Even though Loftus et al. do not come up with an appraisal of the *duration* of the icon, they do supply an estimate of the amount of information that can be extracted from it (i.e., the icon's

This work was supported by Grant A6592 from the Natural Sciences and Engineering Research Council of Canada to Vincent Di Lollo.

I thank Lew Stelmach for commenting on an earlier version of this article.

Requests for reprints should be sent to Vincent Di Lollo, Department of Psychology, The University of Alberta, Edmonton, Alberta, Canada T6G 2E9.

The present commentary was written not to impugn the views of Geoff Loftus—a fellow researcher and respected colleague—but to join in the cooperative endeavor of understanding the temporal course of perceptual events.

worth). Specifically, they suggest that the amount of information recoverable from the icon is equivalent to that recoverable from a 100-ms extension of the original stimulus. The salient point here is that the differences in performance are explained entirely on the supposition that an icon remains visible when the mask is delayed but not when it is immediate.

Internal Representation of a Stimulus

A fundamental assumption made by Loftus et al. (1985) was that each stimulus-picture produced its own—and only one—icon whose worth could then be examined as a function of exposure duration. Here I suggest that the single-icon assumption is not tenable. In addition, I suggest that the paradigm employed by Loftus et al. would not be suitable for studying the effect of exposure duration even if multiple icons were assumed.

Consider Loftus et al.'s first experiment, in which pictures were displayed for durations of up to 1,300 ms. It is likely that up to four or five eye fixations occurred during that interval. In turn, each fixation produced a separate and different image within the visual system, and each image produced (or was) a separate icon. Given that multiple fixation occurred—at least at the longer exposure durations—Loftus et al. cannot claim that each picture produced only one icon. The major problem lies in justifying a single visible icon produced by multiple successive fixations.

For example, by what means can the contents of successive fixations be aligned so as to lie in perfect spatial registration within a picture's icon? And, given that icons fade, how can brightness relationships be maintained? To underscore the significance of these questions, it is necessary to dispel a not uncommon but quite inaccurate belief regarding the internal representation of a stimulus—namely, that a stimulus enters the visual system as a total display with all its details in place even if its angular size far exceeds the scope of foveal vision. The truth is that, outside about two degrees of foveal vision, the retinal image becomes progressively degraded through a precipitous drop in spatial resolution and, at greater eccentricities, through deterioration in color vision. For example, at an eccentricity of 10°, resolution is only 20% of that at the central fovea. Hence, not only will retinal images produced by separate eye fixations have different contents but also subsets common to two or more images will have different spatial and chromatic spectral compositions. These and related problems must be resolved before postulating a unitary icon from multiple fixations. Indeed, it was with the express purpose of avoiding the problem of multiple fixations that earlier studies of iconic memory employed stimuli whose durations did not exceed the estimated latency of a saccade (180–250 ms, according to Alpern, 1971). The conceptual framework adopted by Loftus et al. depends critically on the assumption of a single icon and would require major alterations to accommodate more.

One solution would be to regard the internal representation as *schematic* rather than visible, much along the lines suggested in a different context by Hochberg (1971) and by Arbib (1975), among others. On this option, the internal representation of a scene would consist of an informational schema, and the role of multiple fixations would be to augment or update the information contained in the schema. But this would be a concept fundamentally different from that of the icon, and neither Hochberg nor Arbib would consider such schematic representation to be *visible.* This was made clear by Hochberg when he stressed that "schematic maps are not sensory" (Hochberg, 1971, p. 456).

An alternative solution would be to follow Averbach and Coriell (1961), who realized quite early the problem posited by icons produced by successive eye fixations and introduced the concept of *erasure* as follows: "A storage process normally also involves erasure, to assure that old information is out of the store before new information is put in. Otherwise, new information and old would be inextricably merged in the store" (Averbach & Coriell, 1961, pp. 317–318). In a situation such as Loftus et al.'s, the icon produced by each eye fixation would be erased by the contents of the next fixation except for the last icon in the sequence, which was followed by a blank field, unless an immediate mask was presented.

Now let us examine Loftus et al.'s conclusion that the icon's worth as a source of information is independent of exposure duration. What was the exposure duration on which each icon was based? Clearly, it was the duration of the corresponding eye fixation. But, because every icon except the last was immediately erased, only the last icon in a sequence could be used to assess the effects of exposure duration. And what was the duration of stimulus exposure during the last eye fixation for each different picture? Clearly, it was indeterminate because neither onset nor termination of a picture was synchronized with saccadic eye movements. As a consequence, the picture's exposure during the last eye fixation could have varied anywhere between a fraction of a millisecond to the entire duration of the fixation itself. Hence, although the problem of multiple fixations is solved by erasure, no firm inference can be made about the relation between exposure duration and the icon's worth.

In the main, the foregoing discussion applies to exposure durations that permit multiple fixations. But there are other objections that apply whether or not multiple fixations occur. We now turn to those objections.

Are "Icons" Unitary?

A disclaimer is overdue: I do not believe that the icon is a useful concept, not only for the reasons so eloquently stated by Haber (1983, although I do not subscribe to Haber's version of ecological validity) but also because the concept has been used in such indiscriminate fashion that it has come to mean all things to all people. Let me give a thumbnail sketch of the development of the icon from a unitary to a multidimensional concept, and let me then suggest that Loftus et al.'s proposal of a unitary icon must first discount the arguments that support multidimensionality.

In its initial formulation (Neisser, 1967; Sperling, 1960), the icon was regarded as a virtual extension of the physical stimulus that lasted for a brief interval after stimulus termination. Iconologists decreed that its function was to extend the duration of brief stimuli to aid extraction of information (e.g., Haber, 1971). The icon's unitary nature was generally accepted. But it wasn't long before the need for finer classification became apparent. Sperling (1967) first suggested a separation between visible and nonvisible memory traces. The separation was further elaborated by Turvey (1978), who also distinguished two components: a brief visible component (*visible persistence*) and a more durable nonvisible component (*schematic persistence*). Turvey (1978) regarded visible persistence as being visible, brief, susceptible to masking, of indefinitely large capacity, and tied to a fixed retinotopic location. By contrast, schematic persistence was regarded as nonvisible, temporally substantial, nonmaskable, of limited capacity, and not tied to a fixed retinotopic location.

Separation of "iconic memory" into at least two (but probably more) components is dictated by compelling evidence that the two components are affected differently by changes in stimulus dimensions such as complexity, intensity, and duration. Phillips (1974) showed that changes in stimulus complexity affect schematic but not visible persistence. Also, increments in stimulus duration *reduce* the duration of visible persistence (Bowen, Pola, & Matin, 1974; Di Lollo, 1977, 1980; Efron, 1973) but leave schematic persistence unaffected (Di Lollo, 1978; Sperling, 1960). Similarly, stimulus intensity affects duration of visible persistence *inversely* (Bowen et al., 1974; Efron & Lee, 1971) but has little or no effect on schematic persistence (e.g., Adelson & Jonides, 1980). On the basis of this and other evidence marshalled in a recent treatise on iconic memory, Coltheart (1980) found it necessary to postulate not two but three separate components of iconic memory, each with different distinguishing characteristics.

On empirical and conceptual grounds, what was known as a unitary icon must be regarded as consisting of at least two (but probably more) separate phenomena that respond differently to given experimental manipulations.

In order to re-establish the icon as a unitary phenomenon, Loftus et al. affirm a new concept of the icon whose visibility is determined by the rate of information processing at any given point in time. This is a bold step which, if developed successfully, would cause a radical change in orientation of research in this field. What is needed is to give a detailed description of how the new principles would account for empirical findings that forced a splitting of the icon. For example, how would they account for Phillips' (1974) finding that visible persistence is unaffected by the complexity of a brief display? If I understand Loftus et al.'s reasoning, a complex stimulus should give rise to higher rates of information extraction over a longer period of time than should a simple stimulus, and hence it should produce a stronger icon. But this expectation would differ sharply from Phillips' (1974) findings. Clearly, what is required is a detailed examination—not a global account—of the extant experimental evidence in terms of the suggested new principles.

Without prolonging this discussion unnecessarily, I submit that any explanation in terms of a visible icon creates a number of difficulties. Below, I suggest an alternative, more parsimonious approach.

An Alternative Account

An icon is not necessary to explain the results reported by Loftus et al.: Well-established concepts of backward masking are sufficient.

Severity of backward masking by pattern is known to decrease as either stimulus duration or interstimulus interval (ISI) is increased (e.g., Kahneman, 1968). In general, severity of masking is held to decrease as stimulus-onset asynchrony (SOA) is increased (e.g., Scheerer, 1973). The results of Loftus et al. show the expected effects of both stimulus duration and of ISI. The *absolute* level of masking decreased as stimulus duration was increased. (In Loftus et al.'s terms, the *absolute* value of the icon's worth decreased as exposure duration was increased). Similarly, the introduction of a 300-ms ISI diminished the effectiveness of the mask at all stimulus durations. In suit with the relation between stimulus duration and severity of masking, the *absolute* advantage conferred by an

ISI decreased as stimulus duration was increased. But the *relative* advantage remained proportionately constant at all stimulus durations. (In Loftus et al.'s terms, the icon's worth, measured in terms of corresponding "additional physical exposure duration," remained constant at all exposure durations.)

It is almost a truism to say that the arrival of a mask interferes with the internal representation of a test stimulus at one or another stage of processing. But this does not mean that the mechanism of masking must be identified with the obliteration of the icon. What, then, is the mechanism of masking? The answer is that there is not one, but many mechanisms. What mechanism is at work in any given situation depends on the nature of the test stimulus, the nature of the mask, the luminous intensity levels, the spatial relationships, as well as on the SOA (see Turvey, 1973). In Loftus et al.'s experiments, in which exposure duration was the major independent variable (plus presence or absence of an ISI), the mechanisms of masking probably depended on the SOA, much along the lines proposed by Scheerer (1973). At brief SOAs (less than about 150 ms) masking occurs through stimulus degradation resulting from luminance summation and integration of the contours of test stimulus and mask (cf. Eriksen, 1966). In this type of mechanism, masking might be mediated by the visible persistence of the test stimulus (see Di Lollo, 1980). At longer SOAs (up to about 300 ms), masking probably occurs by interruption of processing (Kolers, 1968; Scheerer, 1973), but the assumption that either processing or masking is mediated by a visible icon is unnecessary. At even longer SOAs, masking—if it occurs at all—probably occurs through perceptual interference (e.g., Di Lollo & Moscovitch, 1983), a nonvisible process that does not even require spatial superimposition between test stimulus and mask.

Without the icon as the basis for explanation, the results of Loftus et al. would be eminently interpretable on the basis of schematic memorial representations such as those suggested by Hochberg (1971) and outlined earlier in the present article. According to Hochberg, a nonvisible internal representation (*schema*) of a scene is assembled within the visual system from successive eye fixations. Each additional fixation adds details to, or updates, the internal representation. Interpreting the results of Loftus et al. in terms of this theoretical framework would involve two simple steps: First, the point could be made that, as has been shown in Loftus' previous work (e.g., Loftus, 1972), the amount of information extracted from a picture was directly related to the number of eye fixations, with each additional fixation contributing proportionately less information to the schema. And, second, that the information accruing from the last fixation of a picture was degraded by the mask in the *immediate* but not in the *delayed* condition. (The mechanism of masking would depend on the SOA, which, in turn, would depend on the time elapsed between the last saccade and the onset of the mask). The net effect is that more information about the picture would be accumulated in the schema under the *delayed* condition (which had the benefit of n fixations) than under the *immediate* conditions (which had the benefit of only $n - 1$ fixations). Of course, not all of the information contained in a fixation is deleted by the mask: The precise amount depends on such factors as structural similarity and SOA. This is why perception can take place even when test stimulus and mask occur within the confines of a single fixation.

I submit that this account is preferable not only because it avoids the difficulties encountered by an explanation in terms of icons but also because it can encompass all of Loftus et al.'s results (including the superiority of the *no mask* over the *delayed mask* conditions) within a single conceptual framework.

References

Adelson, E. H., & Jonides, J. (1980). The psychophysics of iconic storage. *Journal of Experimental Psychology: Human Perception and Performance, 6,* 486–493.

Alpern, M. (1971). Effector mechanisms in vision. In J. W. Kling & L. A. Riggs (Eds.), *Woodworth & Schlosberg's experimental psychology* (3rd ed., pp. 369–394). New York: Holt, Rinehart, and Winston.

Arbib, M. A. (1975). Parallelism, slides, schemas and frames. In M. A. Arbib (Ed.), *Two papers on schema and frames* (COINS Technical Report 75C-9). Department of Computer and Information Sciences, Amherst: University of Massachusetts.

Averbach, E., & Coriell, A. S. (1961). Short-term memory in vision. *Bell System Technical Journal, 40,* 309–328.

Bowen, R. W., Pola, J., & Matin, L. (1974). Visual persistence: Effects of flash luminance, duration and energy. *Vision Research, 14,* 295–303.

Coltheart, M. (1980). Iconic memory and visible persistence. *Perception & Psychophysics, 27,* 183–228.

Di Lollo, V. (1977). Temporal characteristics of iconic memory. *Nature, 267,* 241–243.

Di Lollo, V. (1978). On the spatio-temporal interactions of brief visual displays. In R. H. Day & G. V. Stanley (Eds.), *Studies in perception* (pp. 39–55). Perth, Australia: University of Western Australia Press.

Di Lollo, V. (1980). Temporal integration in visual memory. *Journal of Experimental Psychology: General, 109,* 75–97.

Di Lollo, V., & Moscovitch, M. (1983). Perceptual interference between spatially separate sequential displays. *Canadian Journal of Psychology, 37,* 414–428.

Efron, R. (1973). An invariant characteristic of perceptual systems in the time domain. In S. Kornblum (Ed.), *Attention and performance IV* (pp. 713–736). New York: Academic Press.

Efron, R., & Lee, D. N. (1971). The visual persistence of a moving stroboscopically illuminated object. *American Journal of Psychology, 84,* 365–375.

Eriksen, C. W. (1966). Temporal luminance summation effects in backward and forward masking. *Perception & Psychophysics, 1,* 87–92.

Haber, R. N. (1971). Where are the visions in visual perception? In S. J. Segal (Ed.), *The adaptive function of imagery* (pp. 33–48). New York: Academic Press.

Haber, R. N. (1983). The impending demise of the icon: The role of iconic processes in information processing theories of perception. *Behavioral and Brain Sciences, 6,* 1–11.

Hochberg, J. (1971). Peception II. Space and movement. In J. W. Kling & L. A. Riggs (Eds.), *Woodworth and Schlosberg's experimental psychology* (3rd ed., pp. 475–550). New York: Holt, Rinehart, and Winston.

Kahneman, D. (1968). Method, findings, and theory in studies of visual masking. *Psychological Bulletin, 70,* 404–425.

Kolers, P. A. (1968). Some psychological aspects of pattern recognition. In P. A. Kolers & M. Eden (Eds.), *Recognizing patterns* (pp. 4–61). Cambridge, MA: MIT Press.

Loftus, G. R. (1972). Eye fixation and recognition memory for pictures. *Cognitive Psychology, 3,* 525–551.

Loftus, G. R., Johnson, C. A. & Shimamura, A. P. (1985). How much is an icon worth? *Journal of Experimental Psychology: Human Perception and Performance, 11,* 1–13.

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

Phillips, W. A. (1974). On the distinction between sensory storage and short-term visual memory. *Perception & Psychophysics, 16,* 282–290.

Scheerer, E. (1973). Integration, interruption and processing rate in visual backward masking. *Psychologische Förschung, 36,* 71–93.

Sperling, G. (1960). The information available in brief visual presentations. *Psychological Monographs, 74,* 1–29.

Sperling, G. (1967). Successive approximations to a model for short-term memory. *Acta Psychologica, 27,* 285–292.

Turvey, M. T. (1973). On peripheral and central processes in vision: Inferences from an information processing analysis of masking with patterned stimuli. *Psychological Review, 80,* 1–52.

Turvey, M. T. (1978). Visual processing and short-term memory. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes* (Vol. 5, 91–142). Hillsdale, NJ: Erlbaum.

Received November 26, 1984 ■