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# On Worthwhile Icons: Reply to Di Lollo and Haber

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In response to Haber: First, icons can be spatiotopic as well as retinotopic. Second, knowledge of icons is necessary for designing video-display systems. Third, ecological validity should not be a criterion for the scientific investigation of some topic. In response to Di Lollo: His general model does not account for several salient aspects of the Loftus, Johnson, and Shimamura (1985) data. I propose a model that is similar to Di Lollo's but that involves visual rather than schematic persistence. This model is supported by results of a new experiment.

Di Lollo (1985) and Haber (1985) address somewhat different issues. Di Lollo challenges our conclusion[1] that an icon can be characterized as a visible extension of the physical stimulus and offers an alternative interpretation of our findings. Haber, on the other hand, rejects the entire concept of an icon as a suitable topic of scientific study.

Both Di Lollo and Haber assume that the icon under consideration is *retinotopic*, that is, tied to retinal coordinates as, for instance, would result from photoreceptor persistence (cf. Sakitt, 1976). In fact, however, we were deliberately silent about whether the icon in our experiments was retinotopic, with a separate icon associated with each eye fixation, or spatiotopic, that is, tied to environmental coordinates and stable over a series of eye fixations. We did not think that our data distinguished between these two possibilities, and such a distinction was not central to the point of our experiments. But because both Haber and Di Lollo have raised the issue, I will address it here.

The notion of a spatiotopic icon will figure in my replies both to Di Lollo, and to Haber. Some preliminary remarks on the current status of that concept are appropriate.

Until recently, evidence was strong for a highly literal, central visual store into which environmental information was mapped and integrated across a series of eye fixations. This evidence derived, in large part, from experiments in which two stimuli, presented in the same spatial location but during different eye fixations—and thus in different retinal locations—were apparently integrated, much as if they had been presented simultaneously (Breitmeyer, Kropfl, & Julesz, 1982; Davidson, Fox & Dick, 1978; Jonides, Irwin, & Yantis, 1982; Ritter, 1976; Wolf, Hauske, & Lupp, 1978, 1980).

However, the most impressive of these demonstrations (Jonides et al., 1982) was shown to result mostly from an artifact of cathode-ray tube (CRT) persistence (Irwin, Yantis, & Jonides, 1983; Jonides, Irwin, & Yantis, 1983; Rayner & Pollatsek, 1983). These failures of literal visual integration, along with other such failures (Pollatsek, Rayner, & Collins, 1984; Rayner, McConkie, & Zola, 1980), rule out some forms of a spatiotopic icon, at least when alphanumeric material, line drawings of objects, or random-point patterns are used as stimuli.

It does not, however, seem appropriate to abandon the entire concept, particularly as it might apply to the kind of complex, real-world scenes used in our experiments. Pollatsek et al. (1984), demonstrate that, even for line drawings there is an integrative buffer, lasting across saccades, that is visual in several respects. More fundamentally, however, it is an inescapable truth that the environment is perceived to be stable, despite the instability of the retinal image over eye fixations. This phenomenon must depend on some kind of visual, environmentally stable internal representation.

## Haber's Comments: Are Icons Worth Studying?

Haber essentially reiterates the arguments that he presented in his well-known *Behavioral and Brain Sciences* article (Haber, 1983). These arguments are as follows. First, visible persistence plays no obvious role in everyday perceptual activity. Second, retinotopic persistence would actually interfere with perception in a variety of ways, and therefore we shouldn't have it (although Haber doesn't seem to dispute the experimental evidence

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[1] For ease of discourse, I refer to the Loftus, Johnson, and Shimamura (1985) experiments in the first person plural.

that we do). In his present commentary, Haber remarks further that 100 ms of additional physical exposure duration wouldn't help very much in everyday perception whether the 100 ms resulted from the stimulus itself or from an icon. Haber makes it clear that his views on the suitability of the icon as a topic of scientific investigation have not changed in the past 2 years.

Haber's (1983) arguments (and, by extension, his present arguments) were rebutted, on a variety of grounds, in 40 journal pages by 30 of the 32 commentators on his article. Given the breadth and richness of this discussion, it doesn't seem especially fruitful to fill additional journal space detailing here the various objections to Haber's assumptions and conclusions. Instead, I will briefly sketch some of what I consider to be the major points made by the commentators and provide selected references.

*Retinotopic Versus Spatiotopic Icons*

Throughout both his 1983 article and the present commentary, Haber assumes a retinotopic icon. The major problem with this position is that, although everybody seems to agree that we "see" an icon, everybody also seems to agree that we don't "see" what's on the retina. Rather, it's generally assumed that we see and extract information from some more central representation. Coltheart (1983) and Breitmeyer (1983; see also Breitmeyer et al., 1982) make this point quite cogently. Whereas visible persistence from a retinotopic icon would not be useful and, indeed, might be detrimental in the way that Haber describes, persistence from a spatiotopic icon could be useful in ways that are detailed by various of the Haber (1983) commentators.

*Practical Considerations*

Let us, for the moment, set aside the arguments made in the first point above and examine Haber's assumption that the normal, external, visual environment is continuously available rather than intermittent. Until about a century ago, this assumption was, for the most part, quite reasonable. However, the invention of the motion picture projector heralded the beginning of an era in which people did occasionally observe an environment presented as a series of brief flashes that, to be correctly perceived, had to be somehow integrated.

Such artificial visual environments have steadily proliferated since then; indeed, the past decade has produced an explosion of computer-based, visual technology whose effect has been that people now spend a great deal of their time looking at displays that are dark much of the time. In order to build video display systems in which perception occurs in some specific, desired way, knowledge of visible persistence and of the information extracted from an icon is crucial.

*The Curse of Ecological Validity*

And finally, let us for the moment set aside the arguments made in the first two points above and examine Haber's fundamental premise that the ecological abundance of some phenomena constitutes a necessary condition for scientific investigation of that phenomenon. As I have pointed out earlier,

> This is certainly one point of view but it is a point of view that runs counter to scientific wisdom and practice developed over the past few millennia. From this point of view, for example, one would ignore the recent discovery of the monopole, since this illusive particle doesn't seem to play much of a role in everyday physical activity. Similarly, if one were studying gravity, one would shy away from experiments involving objects falling in near vacuums, or balls rolling down near-frictionless inclined planes, since one would be hard pressed to find such artificial situations in the real physical world. One would concentrate instead on exploring phenomena that are more ecologically abundant, such as leaves drifting gently from trees or rocks bouncing down bumpy hillsides (Loftus, 1983, p. 28).

A number of other commentators of Haber (1983) have made similar points. Uttal (1983), discussing the use of icons as laboratory tools, coined the term *perceptual fruit flies*. Uttal's point was that, even ignoring whatever normal perceptual functions icons might serve, they are indisputably useful for studying a variety of perceptual phenomena. As one example, visible persistence has recently been used to study fundamental spatial interactions in the visual system (Farrell, 1984; Di Lollo & Hogben, 1985).

Sperling (1983) makes the more fundamental point that "we need iconic memory in our theories because, while our theories may intend ultimately to deal with normal perception, they are almost invariably tested with the tachistoscopes (or their modern offspring, computer driven cathode ray tube displays) and it would be pointless to have a theory that did not pertain to the experiments that purportedly established it (p. 38)." Thus, a theory of the icon is necessary for appropriately interpreting the results of any laboratory experiment in which an icon occurs.

In summary, I've chosen to sketch out three of the more salient objections to Haber's fundamental thesis. First, an icon deserves investigation because it is an obvious and robust part of various laboratory paradigms. Second, current video display technology requires us to know about icons and visible persistence out of necessity. And third, the icon under consideration here is probably a spatiotopic icon rather than the sort of retinotopic icon about which Haber complains. This last point relates to Di Lollo's comments (1985), and I now consider it in somewhat more detail.

## Di Lollo's Comments: What Accounts for an Icon's Worth?

Di Lollo criticizes our conclusion that our results are adequately explained in terms of a visible icon. Like Haber, Di Lollo takes it for granted that we assume a retinotopic icon, and he sketches several problems that a retinotopic icon would raise, particularly in our Experiment 1, wherein stimulus durations were sufficiently long that multiple eye fixations were possible.

### *Di Lollo's Eye Fixation/Masking Interpretation*

Di Lollo then offers an alternative interpretation of our data that incorporates essentially three assumptions.

1. A series of eye fixations over a picture results in the construction of a nonvisible, schematic representation of the picture (e.g., Hochberg, 1971; Turvey, 1978).
2. The more eye fixations on the picture, the more complete is the schematic representation and the better is memory performance. This accounts for the benefit of increased exposure duration.
3. Information from the last fixation on a picture is degraded by a mask in an immediate-mask presentation but not a delayed-mask presentation. This accounts for the benefit of delayed-mask conditions over immediate-mask conditions.

This interpretation, although useful in many respects (see below) and although not inconsistent with our results, isn't precise enough to account for two important characteristics of our data: the robustness of the icon's worth and the single-fixation results.

*Robustness of the icon's worth.* We found that an icon is worth 100 ms of additional physical exposure duration under a very wide array of circumstances. This 100-ms figure was independent of the picture's physical exposure duration; moreover, it held up over four different sets of pictures, three different dependent variables, and two values of stimulus luminance. This invariance of an icon's worth (albeit, not the specific value of 100 ms) is a necessary consequence of the single, simple assumption that whatever information-extraction processes operate during a picture's physical presence also continue to operate for a short period of time after the picture has physically disappeared. We found strong evidence supporting this assumption in our Experiment 4, wherein a particular independent variable—stimulus luminance—affected the picture and the icon in quantitatively identical ways.

According to Di Lollo's account, the qualitative superiority of the delayed-mask conditions over the immediate-mask conditions occurs for different reasons in different circumstances. (In particular, Di Lollo believes that the processes that give rise to the delayed-mask superiority change as a function of stimulus duration.) But if such were the case, then it must follow that qualitatively different cognitive processes produce the same quantitative worth of the icon over a wide variety of circumstances. This would be a truly stunning coincidence.

*Single versus multiple eye fixations.* Di Lollo's account is designed principally to deal with multiple-fixation stimulus presentations. Its application to single-fixation presentations is unclear: Di Lollo says only, "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 (p. 382)." However, it was only in our Experiment 1 (and to a small degree in Experiment 2) that presentation times were sufficiently long to allow multiple fixations. Indeed, our conclusions relied chiefly on data stemming from the short presentation-time conditions of Experiments 2–4 in which only a single fixation was allowed.

### *Spatiotopic Icons?*

A variation of Di Lollo's account that seems more promising is one that was explicated in most detail by Breitmeyer (1983; Breitmeyer et al., 1982). Breitmeyer and his colleagues first make a careful distinction between retinotopic and spatiotopic icons. Based in part on the classic experiment of Davidson, Fox, and Dick (1973), they argue that a retinotopic icon is tied to retinal coordinates, is nonvisible ("previsible" in their terms), is subject to metacontrast, and is ordinarily masked by the new retinal image that results from the next eye fixation. A spatiotopic icon, in contrast, is tied to environmental coordinates, is visible, and, although not subject to metacontrast, is maskable by the kind of noise mask used in our experiments. This spatiotopic icon is a suitable candidate for the entity whose characteristics we were investigating.

This kind of spatiotopic icon is similar, in some respects, to the "schematic representation" suggested by Di Lollo. Both are dissociated from retinal coordinates, and both are constructed by a series of eye fixations over the scene. The major difference between them is that Di Lollo assumes his schematic representation to be nonvisible, whereas Breitmeyer et al. assume their spatiotopic icon to be visible.

Actually, Di Lollo's account of our data is a bit more complicated than this, because he really doesn't commit himself to a nonvisible, schematic representation following very short stimulus durations. Rather, he assumes that a noise mask interferes with different mental representations at different stimulus-mask onset asynchronies (SOAs). He states that at brief SOAs (less than about 150 ms), masking operates via luminance summation, possibly on a visible representation of the target stimulus. At longer SOAs, however, "the assumption that either processing or masking is mediated by a visible icon is unnecessary" (p. 382).

This reasoning leads to a fairly clear prediction. A noise mask immediately following a short target stimulus (and hence presented at a short SOA) may operate on a visible representation of the stimulus; however, a noise mask immediately following a long target stimulus (and hence presented at a long SOA) must operate on a nonvisible representation.

John Hogden and I have recently tested this prediction using a paradigm introduced by Loftus and Ginn (1984). In this paradigm, target pictures are followed by either a dim or a bright noise mask, and memory performance for the pictures is subsequently tested. The major question is: Does mask luminance affect performance? If it does, then the mask is assumed to be operating on a visible representation of the picture; if it does not, then the mask is assumed to be operating on a nonvisible representation.

In Hogden's and my experiment,[2] target pictures were presented for either short durations (20 ms) or long durations (270 ms). The targets were followed, either immediately or after a 250-ms interstimulus interval (ISI), by a noise mask that was either bright or dim.

The results of this experiment were unambiguous. For each of the two target stimulus durations, mask luminance had a large effect when the mask followed the target immediately but had no effect when the mask was delayed by 250 ms. It is noteworthy that the 270-ms target/0-ms ISI (immediate mask) condition and the 20-ms target/250-ms ISI (delayed mask) condition involved identical SOAs (270 ms). Yet, mask luminance had a large effect when ISI was 0 and no effect when ISI was 250 ms. These results suggest that a picture, presented for whatever duration, is followed by a visible representation that has vanished by 250 ms following the picture's offset.[3]

In summary, the interpretation offered by Di Lollo does not account quantitatively for our data, and the interpretation is disconfirmed qualitatively by the new data that I have just described. A more promising interpretation is similar to di Lollo's but it incorporates a visible, spatiotopic icon as described by Breitmeyer et al. (1982).

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[2] This experiment was inspired by very fruitful discussions with Vince Di Lollo about the issues that he raises in his commentary.

[3] That is, ISI, not SOA, was the critical variable. This finding seems at odds with results reported by Di Lollo (e.g., 1980), who investigated visible persistence of simple dot patterns using a temporal-integration paradigm. Di Lollo found that persistence had entirely disappeared at an SOA of about 200 ms, regardless of ISI. This fascinating inconsistency may be due to differences in the experimental paradigm and/or differences in the nature of the stimuli.

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