Iconic memory and its relation to perceptual processing and other memory mechanisms*

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Research on iconic memory is reviewed. Specific issues discussed include the duration of the icon, effects of stimulus variables, types of information lost, selection, processing capacity, and scanning. More general issues include the level of encoding in the icon and its relation to short-term memory. It is also argued that a number of experiments do not show what they were intended to show because of possible methodological problems. The view is developed that iconic memory is postretinal but uncoded; nor is it influenced directly by strategies or subsequent mechanisms.

The idea of a brief, time-dependent memory serving as an early stage in the analysis of information has existed for a long time (Muller & Pilzecher, 1901, cited in Woodworth & Schlosberg, 1954). Hebb (1949) employed the concept in his two-stage theory of memory. He suggested that memory consisted of a brief neural activity phase (lasting approximately $\frac{1}{2}$ sec) and a second permanent, structural trace. In his theory, the function of the activity phase was to maintain the information until the structural cell assembly could be established. Subsequently, many other investigators have also incorporated a two-stage memory concept into their theoretical frameworks. For example, Broadbent (1958) used the concept to explain some of his observations in dichotic listening.

The first clear behavioral evidence in support of such a time-dependent memory came in Sperling's (1960) work, in which he showed a decline in accuracy during the first few hundred milliseconds following a brief tachistoscopic exposure (cf. Boynton, 1972). Sperling's work was soon supported by the results of Averbach and Coriell (1961), and subsequent investigators have generally found support for Sperling's results. Theorizing about Sperling's work came more slowly, but Neisser's (1967) theoretical discussions served to solidify the notion of a rapidly decaying memory. Of course, as the empirical work became available, the notion of iconic memory has become more definite. In general terms, iconic memory can be described as a large-capacity, short-duration image.

It is a central memory and appears to hold material in a fairly literal form. Obviously, the mechanism is sensory-specific, and thus theoretical notions, including iconic memory, are limited to cases less general than Hebb's suggestions concerning a brief activity trace. Nevertheless, some theorists appear to assign iconic memory a role not unlike that required by Hebb (e.g., Haber, 1971).¹

In addition, there are practical implications of the phenomenon as well. For example, in everyday tasks, such as reading, we know that information is primarily taken in during fixations (Erdmann & Dodge, 1898, cited in Woodworth & Schlosberg, 1954; Latour, 1962; Yarbush, 1967). Eye movements are important, of course, in determining the rate of reading and the sequence of fixations. Clearly, however, mechanisms other than eye movements must be involved in making spatial-to-temporal conversions on information taken in during a single fixation. [For one approach to the problem, see Bryden (1967).] Although perceptual events during single fixations have been studied extensively with tachistoscopes since Cattell's (1885) work, only recently have investigators realized that iconic memory is central to most of the research.

The aim of the present paper is to review the perceptual processing literature related to time-dependent visual memory. Considerable emphasis is given to the partial-report tachistoscopic procedure. There is, however, a semantic problem involved in the experiments, because many different labels have been used: iconic memory (Neisser, 1967), sensory memory, preperceptual memory, visual short-term memory, visual persistence, etc. The terms are not precise, but all include the idea of a highly labile internal representation. We will use the term "iconic memory" to refer to this memory (Neisser, 1967), and will also make distinctions between iconic memory and short-term memory.

A number of issues will be considered in the present

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paper. Discussion on each of the issues will be distributed through the paper. First, the status of iconic memory will be considered in terms of its locus and the level of encoding used in storing information. The conclusion is that iconic memory is postretinal, but that material has not yet been recoded into the form for perceptual and cognitive processing. Second, consideration will be directed to some methodological problems concerning the partial-report task. In particular, the partial-report task developed by Sperling appears to be different from the probe task developed by Averbach and Coriell. For the Sperling task, the argument will be made that the cue does not affect iconic memory directly but, rather, has an indirect influence by determining the order of transfer into short-term memory. Third, the relation of iconic memory to other mechanisms, such as short-term memory, will be explicated.

The organization of the paper follows a different, but more convenient, line of questions, namely, those issues which have motivated researchers. The paper is divided into three major sections. The first deals with the existence of iconic memory and delineation of the variables which influence the icon. The second deals with the relation of the icon to other memory mechanisms, while the third provides an example of the usefulness of the icon as applied to other research problems.

EVIDENCE FOR ICONIC MEMORY

Much time and effort has been expended upon the establishment of the icon as a separate memory. Although some investigators attempted to argue against the notion (e.g., Eriksen & Steffy, 1964), it survived, and subsequent literature shows the focus of interest shifting to the determination of the parameters that affect iconic memory and the properties of the icon. The present section is a review of some of those data together with some interpretive comments.

The Partial-Report Experiment

A substantial amount of evidence about iconic memory derives from experiments using a partial-report technique. In such experiments, a target stimulus is given tachistoscopically, followed by a cue stimulus. The S is required to identify the portion of the target specified by the cue. There are a number of specific ways that one can set up such an experiment. However, following the precedent established by Sperling (1960) and Averbach and Coriell (1961), most investigators have used one of two simple variations of the partial-report paradigm. The probe procedure (Averbach & Coriell, 1961) involves one or more rows of letters as the target and a visual marker pointing at the position one of the letters had occupied. In the procedure popularized by Sperling

(1960), the target consists of several short rows of letters and the cue is a coded tone which indicates report of one of the rows. There are several important differences between the two cases. Nevertheless, at a gross level, the two procedures yield highly similar results. Specifically, the general effect of delaying the cue on accuracy of report is the same. With an immediate cue, the accuracy of report is high, and as the cue is delayed, accuracy declines monotonically. The asymptote of the delay curve occurs at a point between 250 and 1,000 msec after termination of the target stimulus.

The decrease in performance associated with a delay of the partial-report cue is the basic evidence defining iconic memory. Although many details require clarification and qualification, the general interpretation follows the logic outlined below. First, in free-recall, performance is limited by the memory span (Woodworth & Schlosberg, 1954). With the partial-report technique, the memory span limitations can be avoided, presumably by sampling from the information available. The high level of performance at short cue delays indicates a virtually unlimited availability of material. Thus, in contrast to the memory span, the high level of performance in partial report with an immediate cue suggests that a great deal more information is available than can be stored normally in short-term memory. Thus, the evidence forces one to argue that two memory systems are involved, an initial high-capacity system and a subsequent small-capacity system.

The contrast between the estimate of the information available using an extrapolation of a stimulus element-by-element sample (partial report) vs an estimate from full report suggests two memory systems. The interpretation of the delay curve is straightforward when two systems are postulated. The delay function is taken as a measurement of loss from the initial memory system across time. Thus, the delay curve is taken to be a decay curve.

In addition to the basic evidence provided by the partial-report task, other techniques have been attempted. For example, Eriksen and Collins (1967) report an ingenious study showing the persistence implied by the iconic memory notion. Their experiment involved presentation of two fields in rapid succession. Both fields contained a "random" dot pattern, and when the fields were superimposed, the dots outlined three letters. By manipulating the interval between the two displays, Eriksen and Collins were able to control the legibility of the characters. Performance was asymptotic but above chance at the 300-msec delay and longer, which, like data from other experiments, shows that some information gets through into more permanent form.

Duration of the Icon

Many estimates of the duration of the icon appear

to converge upon $\frac{1}{4}$ sec (e.g., Haber, 1971; Haber & Hershenson, 1973). Haber suggests a relation between the duration of the icon and the minimum latency for eye movements. The evidence, however, is not all that clear. Indeed, the $\frac{1}{4}$ sec seems to be a lower estimate rather than the typical value. Sperling (1960) found that accuracy continued to decline for 1 sec after the target exposure in his partial-report procedure. Others have reported durations well in excess of $\frac{1}{4}$ sec (e.g., Clark, 1969; Dick, 1969, 1970; Dick & Loader, 1974; Doost & Turvey, 1971).

There are difficulties in estimating the duration of the icon. In most experiments, the requirement for the S is to identify one or more characters. It is possible that the inability to do so does not reflect a complete loss of information but, rather, a loss sufficient to make identification difficult. It remains possible that other tasks could show that the icon retains useful information for even longer (e.g., Eriksen & Steffy, 1964). The duration is important because of the theoretical developments based on the assumption of the $\frac{1}{4}$ -sec iconic image. Many theorists appear to assume a second kind of visual memory which lasts much longer than the $\frac{1}{4}$ sec usually assigned to iconic memory. Specifically, the iconic duration is too short to account for some of the effects observed. If one admits the possibility that estimates of duration may be influenced strongly by the processing demands and response demands placed on the S, it is not necessary to postulate two distinct visual memory mechanisms. (See, for example, Craik (1973) and Shallice and Warrington (1970).]

Differentiation Between the Icon and Afterimages

It has long been known that afterimages decay in strength over time. Because iconic memory shows a similar decline, it is important to consider whether the two phenomena are one and the same or whether they differ in some important way. The general consensus seems to be that afterimages can be accounted for in terms of peripheral mechanisms (cf. Brown, 1965). Indeed, Julesz (1971) notes that no cyclopean afterimage has ever been reported; a point that is consistent with, but not conclusive for, the peripheral interpretation. Further, it is known that afterimages vary in strength in relation to the amount of dark adaptation, although dark adaptation is not a necessary condition. Also, afterimages can be masked by introducing an illuminated field following the test flash. It might be noted that most investigators using tachistoscopic presentations have employed uniformly illuminated fields preceding and following the brief test flash which should probably eliminate the possibility of a negative afterimage. That is not to say that negative afterimages cannot be produced in a tachistoscopic situation, because they can. The necessary conditions seem to require either dark fields preceding and following a brief exposure or long

inspection of the stimulus followed by an illuminated field. Under these conditions, a negative afterimage can be seen clearly, but it is eliminated when brief exposures are followed by illuminated fields. It is precisely in this latter condition that iconic memory is observed. Thus, an icon does not seem to be a negative afterimage.

The differentiation between a positive afterimage and the icon, however, is another matter, because the positive afterimage is perfectly correlated with the description of an icon.² Some investigators have claimed that afterimages are cortical (cf. Brown, 1965). Some recent work with outline squares comparing stabilized images with afterimages shows similar patterns of disappearance for the two techniques as well as for steady fixation (MacKinnon, Forde, & Piggins, 1969): Sides of the square disappear, never parts of a side. The stabilized image procedure presumably samples cortical events (Pritchard, 1961; cf. Cornsweet, 1970), and, therefore, the correlation between the two procedures implies a common mechanism for the two. Recent physiological and psychophysical work strongly implies a cerebral locus for form perception (e.g., Julesz, 1971). Therefore, it is not unreasonable to suggest that the neural analysis within the afterimage context requires the participation of cortical units for form perception; peripheral neural units would continue to provide input to the cortex. Thus, the possibility remains that some portion of an afterimage (especially the positive portion) is a result of cortical mechanisms and it is this portion that cannot be differentiated from the icon.

Within the tachistoscopic situation, it can be shown that the phenomena of interest are not peripheral. One convenient way of localizing events at a cortical level is to employ dichoptic presentations. Julesz (1971) has pointed out that a failure to obtain an effect under dichoptic conditions does not rule out a cortical locus, because binocular rivalry might overpower the effect of interest. Therefore, when one does demonstrate a dichoptic effect, there is reasonable evidence to imply a cortical locus. In this context, Averbach and Coriell (1961) report that a metacounter ring was equally effective at disrupting report of one letter in the array whether the stimuli were presented binocularly or dichoptically. Further, work by Turvey (1973) and Barry (1974) on backward masking shows that dichoptic masking is dependent upon the type of mask used. Because the dichoptic presentation produces masking, these results imply that some forms of backward masking cannot be peripheral. Dichoptic masking, however, is never stronger and is often weaker than monoptic masking, which implies some peripheral involvement. The magnitude of the difference could be used, although no one apparently has done so, to measure the degree of central or peripheral involvement. Flash masks appear to have their effect at a peripheral level,

whereas pattern masks appear to have predominately central effects. Taken together, these data seem to suggest that an icon is largely a cortical phenomenon, although it cannot be differentiated from a cortical afterimage.

Stimulus Variables

As Neisser (1967) suggests, manipulation of simple physical variables such as luminance and duration ought to provide useful information about both the locus and the nature of iconic memory. Energetic influences can have two distinguishable forms; the duration of the icon can be changed or the rate of loss from the icon can be influenced. If iconic memory is a sensory-like system, one would expect energy manipulations to influence the intercept value of the decay function but have little influence on the rate of decline. With exceptions to be discussed below, the general influence of luminance appears to be on the level of performance and the duration of the icon not on the rate of loss. Duration of exposure appears to have little effect.

Although manipulation of energy variables may seem straightforward, such experiments involve a number of methodological traps. In particular, it is necessary to avoid confounding the manipulation of interest with effects known to influence performance at a sensory level. The issue can be illustrated with reference to an experiment by Sperling (1960). He reported a simple experiment which appears to consider the duration of the icon. Specifically, if the postexposure field was dark, the icon appeared to last as long as 5 sec. However, with a light postexposure field, its duration was reduced to about 1 sec. Mackworth (1963) has reported similar data. However, the manipulation of postexposure luminance is not necessarily relevant to the duration of the icon. For example, changing from a lighted field to a dark field both changes the state of adaptation and introduces the possibility of confounding afterimages.

Background Luminance

Because most investigators have used black forms on white background, the luminance reported refers to the background. Energy manipulations in tachistoscopic experiments involve changes in the amount of light at the eye; but such manipulations seldom involve a change in the contrast ratio, because both the targets and background reflect a constant percentage of incident light. Furthermore, the precise specification of luminance levels is exceedingly difficult, such that the reported values may be in error by as much as 50% (Steiner, 1973, 1974).

Eriksen and Collins (1968) manipulated the luminance of two successive fields independently. Each field contained random dots which, when superimposed, formed three letters. Unlike the Eriksen and Collins (1967) experiment, the dots were

illuminated against a black background. The logic was that the higher the level of the initial flash, the higher the starting point of the decay function. Thus, if a 5-mL flash is followed by a 2-mL flash, performance should be higher than if the opposite sequence were presented. In general, the data support the idea that a higher energy will create a higher intercept value for the decay function, and they show different rates of decay. However, the data are not entirely straightforward; the 5-1 and 1-5 flash-luminance combinations presented simultaneously do not provide performance as high as a 1-1 pair presented simultaneously. As the authors point out, the situation is more involved than just a decaying trace. Because their Ss were dark-adapted, it is likely that some brightness reversals (Barry & Dick, 1972) were taking place and adding to the decay rate. As a result of the potential confound, it is not possible to determine if rate of decay changes with luminance.

Keele and Chase (1967) also showed the rate of decay to vary with luminance level in addition to the overall performance level. Ss in their experiment were also dark-adapted, however, and the interval between the termination of the stimulus and the initiation of the visual indicator was also dark. The luminance levels used were 3.7, 16, and 70 fL. It is known that the brightness of an afterimage is increased with increases in luminance and that the decay characteristics are exponential in time (Brown, 1965). Thus, the use of a dark pre- and postexposure field may account for the results, because the procedure would insure that Ss had available a retinal afterimage.

In another experiment, Eriksen and Rohrbaugh (1970a) controlled the adaptation state of their Ss and reduced the possibility of afterimages by using light pre- and poststimulus fields. They showed letters at either 0.7- or 7.0-mL background luminance. Using a bar marker as a single item cue, they found a small, but statistically significant, effect of luminance on performance. On the average, performance was less than 10% better for the higher luminance; and there was no interaction of luminance with delay of the cue. At the same time, the decrease in accuracy due to delay of the cue was on the order of 25% for both luminance conditions. Light-adapted Ss were also used in a study of Scharf and Lefton (1970), who measured decay at two luminance levels separated by a log unit. The results showed no difference in the partial-report functions due to luminance.

Although the studies differ in several ways, such as the type of cue (visual vs auditory), some of these procedural factors seem to make little differences. The major factor seems to be whether the Ss are light-adapted or not. Flashing photopic-level stimuli at dark-adapted Ss can introduce several additional variables, such as negative afterimages and brightness

reversals. Accordingly, the data must be interpreted with some caution. The more straightforward data are from the light-adapted conditions: luminance changes level of performance but does not *appear* to change rate of decay.

Exposure Duration

One of the difficulties in examining stimulus duration is the differentiation between the stimulus energy necessary for a criterion level of performance and that level of energy necessary for the stimulus to appear to be clear, i.e., of high contrast. Glanville and Dallenbach (1929) showed that phenomenal appearance judgments and accuracy are not perfectly correlated. In my experience, identification threshold functions are quite steep; a change of just 1 msec occasionally will change performance by 50% or more. The range over which exposure duration will influence identification accuracy is small and typically less than 10 msec. When considering phenomenal impressions in terms of contrast, the threshold function over duration is quite different. Even though one may be able to identify all of the letters at a short (e.g., 10-msec) duration, black letters appear washed out and gray. Increases in duration do not result in increased accuracy, but do result in a much sharper stimulus. The preceding comments are largely introspective, but they illustrate the difference between the energies necessary for correct identification as compared with aesthetic qualities of the stimulus. The above is a restatement of the long-known difference between brightness and form perception. Most of the current investigators use high-contrast stimuli and, as a result, probably severely restrict the range in which exposure duration manipulations can affect accuracy. When energy levels are at threshold, there is evidence for Bloch's law reciprocity holding for form perception (Kahneman, Normall, & Kubovy, 1967).

The effects of the duration of the stimulus on the integrity of the icon have been investigated by several techniques. Sperling (1960) varied the exposure duration from 15 to 500 msec; the number of letters reported did not vary in either a whole-report (immediate memory) or a partial-report procedure. The result suggests that much of the energy contained in a long exposure is redundant and not needed. Similar results have been reported by other investigators. For example, Haber and Standing (1969a) presented a stimulus repeatedly at a fixed rate and asked Ss to judge whether the brief stimulus appeared perceptually continuous or discontinuous. The apparent duration was independent of the exposure duration of the stimulus over a range of 4 to 200 msec. In addition, the apparent duration did not depend upon whether the stimulus was always presented to one eye or alternated between eyes. In another study (Haber & Standing, 1970), Ss adjusted

a click to the apparent initiation of a visual stimulus and another click to its apparent termination. The interclick interval was used as a measure of the apparent duration of the flash. When flash and adapting field luminances were equal, the apparent duration did not track linearly the physical duration; the postexposure component of apparent duration decreased as the physical duration increased. But there is a difficulty here. We have pointed out that identification and clarity are not linearly related. When the same stimulus is repeated, identification is trivial; therefore, Ss must be using an "aesthetic" criterion. Given these cautions, one might suggest that the icon makes a short stimulus appear longer but it is unnecessary if the stimulus is of long duration (Haber & Standing, 1969a, 1970).

Whether one interprets the Haber and Standing (1969a, 1970) experiments as suggesting a change in the duration of the icon or not depends upon the theoretical and methodological stance one takes. One could imagine two polar theoretical positions: in the first, it is assumed that the icon begins when the stimulus is terminated. From this point of view, one might not expect the results obtained by Haber and Standing. The second position is that the icon begins when the stimulus is initiated and runs its course whether the stimulus is present or not. Under this idea, the Haber and Standing data are not surprising. Part of this issue contains a methodological question as to the way one should measure temporal events.³ Basically, the most consistent interpretation seems to be that some portions of the physical stimulus may be irrelevant for identification (Garner, 1965); i.e., we might use only the first few milliseconds of a fixation to take in information for form analysis. A number of investigations have supported the contention (Haber & Nathanson, 1969; Mewhort et al, 1969; Pylyshyn, 1965). To acquire more information, we must make a second fixation (Pylyshyn, 1965), unless the stimulus is subthreshold (Jackson & Dick, 1969).

Although there are experiments in which it has been argued that exposure duration is an effective variable, some of them contain methodological problems. For example, Mackworth (1963, Experiment I) varied exposure duration and found that the number of digits correctly reported in correct position increased with increases in exposure duration. One problem with her experiment is that the pre- and postexposure adapting luminances (39 fL) were much higher than the display (3 fL); because of the luminance difference, the adapting field functions as both a forward and backward mask (Eriksen, 1966). In Mackworth's situation, increasing the duration of the stimulus automatically increases the temporal separation of the masking components; i.e., the contrast-reducing effect of the brighter adapting field is reduced. Her second experiment provides evidence for this interpretation; with flash-masking eliminated,

performance showed a much smaller increase over the first 125 msec. Thus, her results can be interpreted in terms of uncontrolled changes in the amount of flash masking and contrast reduction.

In summary, little can be said about the relation of exposure duration to iconic memory. The relevant manipulations have not been carried out; for example, contrast is known to influence identification (Boynton, 1957). Further, empirical clarification is needed for identification vs aesthetic judgments. At present, the data seem to suggest that duration is unimportant across a wide range. Although these results are not consistent with Bloch's law, Bloch's law does not apply in suprathreshold situations.

Effects of the Cue: Some Methodological Considerations

With a few exceptions, e.g., Eriksen and Colgate (1971), most investigators have ignored the fine details of the partial-report task. For example, few have considered differences in performance imposed by various cues, and, as one might expect, a variety of procedures have been used. Sometimes, simple procedural difficulties have generated some misleading data. For example, both Mayzner et al (1964) and Eriksen and Steffy (1964) have reported failures to replicate the classic decay curve. However, Mayzner et al used light-adapted Ss but included dark intervals between the test stimulus and the partial-report cue. Thus, the adaptation state covaries with the delay of the cue manipulation. Eriksen and Steffy used only two stimulus alternatives. When more alternatives are included, their conditions yield the decay curve (Keel & Chase, 1967). Clearly, one of the conditions required to obtain a decay curve is an overload of the system; i.e., there must be more material than the S can retain without extensive rehearsal in verbal short-term memory. The latter point focuses on one of the more important implications of the decay curve. The capacity of iconic storage is greater than that of verbal short-term memory. The implication, in turn, focuses attention on a further point, namely, in simple free-recall tachistoscopic tasks, one of the chief limitations of performance concerns the Ss' ability to transfer material from iconic storage into a more permanent form.

In delaying the partial-report cue, one delays the instruction indicating what to report. Of course, at the same time, the manipulation delays report. The critical factor, however, is event uncertainty. Thus, delaying report does not produce decay unless one introduces event uncertainty; i.e., uncertainty about what or how to report. For example, Sperling (1960) included a control condition in which a full-report cue was delayed systematically. Accuracy across the delay conditions was not changed. Dick (1967) has replicated the experiment several times, and, in all

cases, accuracy remained stable across the delay conditions.

In considering the simple delay of report control, it is tempting to speculate about the reason no decay is present. For example, one argument is that performance in the free-recall control is at the level of the asymptote of the partial-report decay curve. Unfortunately, the point requires an explicit comparison of performance levels in the two tasks. However, the partial-report task requires report of fewer items than the corresponding free-recall task. Because of the variation of the number of items to report, the tasks differ in terms of output interference in which it is assumed that the act of responding with one item will interfere with the accuracy of the next response to be made. Thus, as Dick (1971a) has shown, the comparison required by the argument cannot be made legitimately.

A variety of techniques have been used to provide the partial-report cue. The best known examples are the tone-row and marker-item techniques of Sperling and of Averbach and Coriell, respectively. Although the pattern of results for the two techniques is basically the same, there are a number of procedural differences. For example, the Sperling experiment uses an auditory cue but the Averbach and Coriell experiment uses a visual cue. Similarly, the Sperling experiment uses recall of more items than the visual technique of Averbach and Coriell. Thus, the Sperling experiment involves output interference effects not present in the visual marker experiment. Also, the S in the Averbach and Coriell task must be able to discriminate more cues than in the Sperling task; i.e., the cue uncertainty is greater in the Averbach and Coriell task. Considering the modality of the cue, the data available suggest that it is not important. Smith and Ramunas (1971) used a vibrotactile cue to indicate report of one element of a six-element visual display. The cue was delivered to three fingers of each hand. Their results were similar to those using more traditional cueing techniques (Averbach & Coriell, 1961).

Although the modality of the cue may not be important, the processing demands of the cue are important. For example, Eriksen and Collins (1969) compared a bar marker cue and a semantic position cue. The cues were presented before the display, simultaneously with the display or after the display. Accuracy was highest with the preexposure cues and declined as the cues were delayed. More important, however, the decline depended on the particular cue; the semantic position cue declined sooner than the bar marker. One interpretation concerns the processing required to use the cue and, in particular, the time required to process the cue (cf. Eriksen & Colgate, 1971; Eriksen & Rohrbaugh, 1970b). If a relatively long time is required to process the cue, the decay of the icon may be complete before the S can sample its

contents. Thus, if one measures a delay of cue with respect to the physical timing of the cue and of the display, a cue requiring a relatively long processing time will yield a relatively flat decay curve. The point here is that performance with such a cue reflects a rather late portion of the decay curve. In short, by taking the time required to process the cues into account, it is possible to show similar decay curves with both cues. As will be discussed in the next section, it is probable that both cues measure loss of spatial information.

Types of Information Lost

The question about what information decays borders on a multidimensional scaling problem. It is known that not all dimensions are treated equally by the S, nor are all dimensions independent of one another (Garner, 1970). The point of interest here is not whether performance is better on some dimensions than on others but, rather, which dimensions show decay and which do not. Just as stimulus parameters of luminance and duration provide data about the definition of iconic memory, an examination of types of information also provides clues to differentiate iconic memory from other forms of memory. The partial-report procedure is especially suited for the evaluation because one can cue according to one dimension and ask the S to report according to another dimension. Sperling (1960) cued his Ss as to which row (spatial cue) to report, and they reported the items in that row. His data show that accuracy of report declined as the cue was delayed, indicating that some information was lost. The partial-report procedure cannot be used uncritically, however, as some experiments show. Dick (1969, 1970) cued different groups of Ss according to row, color, and category of items (letters and numbers). He found that information was lost with the row and color cues but not with the category cue. Nor does decay occur when cueing for normal vs mirror-image letters (unpublished). Similarly, Clark (1969) cued Ss by color and asked them to report shape or cued by shape and asked Ss to report the colors of the shape. She found that the color cue yielded a decay function but that the shape cue did not (personal communication). The results imply two points. First, the loss of information appears to be restricted to some physical dimensions, such as color and shape. Second, the usefulness of a dimension for selection is not related to the decay function (Clark, 1969; Dick, 1971a). As is apparent from the data, the role of a dimension depends in large part on how the S makes use of it (Clark, 1969; Dick, 1970).

The partial-report procedure has some built-in limitations for manipulating dimensions for recall and cueing. Accordingly, versions of the visual probe procedure developed originally by Averbach and

Coriell (1961) have been used by many investigators because of its greater flexibility. The bar marker procedure, of course, is a spatial indicator. Some apparently small variations in the task lead results which fail to show loss of information. For example, Steffy and Eriksen (1965) used one of the forms from the display as a cue either before or after the display and asked Ss to report the position that item had occupied. They used three hard-to-label forms combined with a very long (220-msec) exposure. They claim to have found no decay. However, their statistical analyses are difficult to interpret, because, instead of considering delay as a continuous variable, they broke it into two factors, pre- and postcueing and delay. Although a replot of the data with delay as a single variable suggests a monotonic decrease, the data are difficult to evaluate because of the long exposure duration and the use of unfamiliar forms.

Because of the differences between the Steffy and Eriksen (1965) conditions and those of Averbach and Coriell (1961), we repeated the light-adapted condition of the Steffy and Eriksen experiment (Dick & Loader, 1974). Short exposure durations were used, and, to provide a connection between the different types of cues, three were used: arrowheads, digits, and item cues. To examine the role of familiarity, the Es employed four different sets of stimulus materials. The materials were (a) letters; (b) numbers; (c) familiar geometric forms, i.e., squares, circles, etc.; and (d) unfamiliar geometric forms, each consisting of two straight lines. For the unfamiliar geometric forms, the response was drawn on a template; for the other materials, the response was given verbally. The results in this experiment are quite straightforward. A performance difference was observed: accuracy on the unfamiliar geometric forms was lower than on the geometric forms, which was in turn lower than that on letters and numbers; but even the lowest performance was well above chance. This difference is probably due to encoding mechanisms (Colgate & Eriksen, 1970). With respect to delay of the visual cue, the arrowhead showed clear decreases in accuracy for all four materials. There was, however, no evidence in any condition for a decline in accuracy for the semantic-position cue or for the identity cue, and accuracy was near the asymptotic level for the arrow cue. The failure to observe decay with the semantic position or identity cues is due to the longer processing time required for these cues than for arrowheads (Eriksen & Collins, 1969).

Representation in the Icon

The Eriksen and Collins (1969) data show that the less advance time given to process the cue, the lower the accuracy for both bar marker and semantic position cues. Although these and other data might imply that identity information is lost, an analysis of

Table 1
Source of Inversion Errors in Experiment II (Dick & Loader, 1974)

Type of Material	Type of Cue	Number of Spaces from Correct Item											Proportion of	
		Left						Right					Inversion	All
		-5	-4	-3	-2	-1	0	1	2	3	4	5	Errors to Total	Errors to Total
Letters	Arrow	.00	.00	.04	.11	.50	—	.28	.05	.01	.02	.00	.25	.27
	Digit	.02	.02	.07	.16	.43	—	.15	.12	.02	.02	.00	.25	.31
	Item	.00	.04	.13	.14	.30	—	.23	.07	.06	.02	.00	.48	(.48)
Digits	Arrow	.00	.04	.05	.03	.43	—	.29	.09	.02	.03	.01	.22	.26
	Digit	.02	.06	.05	.06	.31	—	.34	.05	.08	.03	.00	.27	.36
	Item	.00	.03	.06	.15	.26	—	.27	.10	.09	.02	.01	.42	(.42)
Familiar Forms	Arrow	.02	.06	.03	.08	.32	—	.26	.11	.04	.06	.01	.29	.46
	Digit	.03	.03	.07	.09	.22	—	.30	.12	.07	.06	.01	.43	.61
	Item	.04	.08	.09	.11	.26	—	.17	.09	.07	.08	.02	.57	(.57)
Unfamiliar Forms	Arrow	.06	.07	.06	.11	.34	—	.24	.09	.06	.06	.01	.37	.68
	Digit	.05	.07	.04	.08	.25	—	.23	.13	.08	.04	.03	.36	.63
	Item	.02	.07	.06	.13	.23	—	.25	.11	.06	.05	.02	.57	(.57)
	Chance	.03	.07	.10	.13	.17		.17	.13	.10	.07	.03		

Note—The entries represent the proportional frequency of responses removed from the probed item from one to five spaces, given that an error occurred. $N = 432$ per row.

errors shows this not to be the case. For example, Eriksen and Rohrbaugh (1970b) presented a bar marker before, during, or after a letter display. They reported that accuracy decreased as the cue was delayed; however, the frequency of Ss' reporting an item next to the one requested increased, but this was not true for more remote items. This result suggests that the S has identity information available but has lost precise spatial information. Eriksen has suggested that the decline in accuracy is due to a failure to focus attention precisely (cf. Estes, 1972), but the decline may also be due to a decay of spatial information.

A way of examining the alternative hypotheses is provided by analyzing the errors in the probe experiment reported by Dick and Loader (1974). In addition to using arrows and semantic position cues, they used an identity cue in which the S was asked to report the position the probe had occupied in the display. One implication of the attention hypothesis is that the S can "zero" in on the appropriate item without processing all of the items in the display. However, the reduction of processing can occur only when the S has some information about which part of the display contains the relevant item; i.e., with the arrow or the semantic position cue. An attention switch would not be helpful with the identity cue because the switch would be random with respect to the display. Accordingly, the attention hypothesis would predict a different pattern of errors for the identity cue case. By contrast, because it is claimed that spatial information is lost, the decay hypothesis predicts the same pattern of errors across all three cues.

Table 1 shows the previously unpublished inversion error data for the Dick and Loader (1974) probe

experiment. The tabular presentation amounts to a collapse of the diagonals of a stimulus-response confusion matrix. The correct item is aligned with 0; thus, for example, a request for the second item from the left involves one possible error from the left of the probed item and four to the right of the correct item. Because there were no interactions of the source of inversion errors with delay, the data have been collapsed across delay. However, the table does disguise the general increase in inversion errors as the cue is delayed (Eriksen & Rohrbaugh, 1970b). Examination shows that the most frequent source of inversions is the position immediately to the left or to the right of the requested item, and this is true for all three probes and all materials. This suggests that the internal representation of the spatial arrangement of items is less accurate than physical space and perhaps is somewhat more relative.

By contrast, although inversion errors are also found in multiple-item report experiments, these errors account for only a small percentage of the total errors. Intrusion errors are more frequent than inversions, but the most frequent error is one of omission. Furthermore, in the multi-item report case, if one uses a cueing procedure in which Ss are asked to respond according to dimensions other than spatial, such as letter-number category or red-black, inversions are very infrequent between the levels of a dimension. Clearly, then, although the decay characteristics are quite similar between single- and multiple-item report experiments, the pattern of errors is quite different. One cannot treat inversions in the same way as omissions or intrusions. Indeed, the errors in the single-item report case suggest that the S saw the relevant portion of the display but is somewhat uncertain as to its precise spatial

arrangement. When the S erroneously reports an item, it is most likely an item that was adjacent to the one requested. Thus, for visual probes, the data can hardly be interpreted in any way other than to say that the S has lost exact spatial position but not other aspects of the representation (cf. Wickelgren & Whitman, 1970). For multiple-item report, the decline in accuracy is due to both loss of position and loss of items. The difference between single- and multiple-item situations may be due to mechanisms other than iconic memory. Indeed, it seems consistent to suggest that the single-item cueing procedure reflects aspects of iconic memory but that multiple-item cueing reflects short-term memory interactions with iconic memory. Other data are consistent with this view (e.g., Dick, 1972b; Scharf & Lefton, 1970).

Familiarity of the Display

The data on types of information lost suggest that physical aspects such as space and color are lost, whereas learned aspects are not. Amount of learning is closely related to familiarity. There is no evidence for a change in rate of decay as a result of either statistical manipulations of familiarity or structural manipulation. Familiarity does affect performance probably by means of redundancy in the stimulus (Garner, 1972).

Mewhort (1967) presented two rows of eight letters and varied the statistical familiarity⁴ of the rows independently of each other. A postexposure auditory cue indicated to the S which of the rows to report. Although the experiment was not designed to make it especially sensitive to decay, there were decreases in accuracy for both orders of approximation as the cue was delayed. He reported that there were no interactions involving delay, although zero order approximations decreased slightly more than fourth-order approximation. In analogous experiments employing a single-item probe procedure, several experiments have been carried out on several orders of approximation (Lefton, 1973a; Merikle et al, 1971). In these cases, a small difference in performance due to orders of approximation is found, but this difference can be attributed entirely to guessing (Lefton, 1973b). Merikle et al found a 4% difference between first and second orders of approximation, and Lefton found 11% and 16% difference between first and fourth orders in comparable experiments. According to Lefton's calculations, the expected difference between first and second should be about 4% and the difference between first and fourth should be about 12%. Thus, almost the entire performance difference due to order of approximation can be attributed to guessing in the single-item case, which is quite different from the multi-item free-recall case (Mewhort, 1967; Miller, Bruner, & Postman, 1954). At the same time, Lefton

reported an effect of delaying the cue but not interaction of order of approximation with delay. Dick and Loader (1974) found a similar effect with a structural familiarity manipulation.

Overall, then, there is no evidence to suggest that the rate of decay is influenced by the familiarity of the stimulus. The performance differences sometimes observed, therefore, cannot be due to alterations of iconic memory. Although one might wish to argue that the amount of information (in terms of bits) differs for statistical approximations to English, an experiment by Mewhort (1972) shows that the amount of information does not account for benefit of familiarity. Rather, performance differences are due to the way in which items are transferred out of iconic memory into short-term memory and to chunking and rehearsal mechanisms.

A methodological caution is appropriate. Mewhort and Dick (1974) have provided some evidence to differentiate between single-item cueing and free recall in the context of orders of approximation. One part of their experiment constituted a partial replication of an earlier experiment by Mewhort (1966) in which he showed that increasing the spacing between letters destroyed the benefit of higher orders of approximation. Mewhort and Dick reaffirmed this result but simultaneously showed that performance with a bar marker was slightly better with wide than with narrow spacing, replicating previously reported results (Eriksen & Hoffman, 1972b; Eriksen & Rohrbaugh, 1970a). Overall, the data provide a clear demonstration that single-item cueing cannot be used to infer characteristics of processing that occurs during multiple-item report (cf. Smith & Spoehr, 1974).

The Icon and Eye Movements

Many of the data reviewed in prior sections suggest that the function of iconic memory is to maintain an internal representation of the stimulus so that processing may proceed. As such, the icon might be viewed as an artifact of the tachistoscopic procedure, since in the natural environment the duration of the stimulus is seldom restricted. From this point of view, the persisting icon would be redundant, since the physical energies are available long enough for complete processing. The data on duration of exposure, however, suggest that the physical presence of the stimulus is redundant and that the icon is used for identification and form perception. One experiment in which the availability of the physical stimulus makes a difference on performance is also a case in which it is possible to make two fixations (Pylyshyn, 1965). The saccadic eye movement between fixations may have several important functions. The first is an acuity effect in which an eye movement will have the function of moving a portion of the stimulus to a more sensitive area of the retina. Performance

should increase, because those portions of the stimulus which were on less sensitive areas of the retina on the first fixation are "moved" to more sensitive areas on the second fixation and, hence, average resolution across the entire stimulus should increase.

There are situations, of course, in which the entire stimulus will fall on the fovea. When this occurs, a second fixation will not serve to move the stimulus to more sensitive positions of the retina. It is in this case that a second function of a second fixation is most apparent, that of generating a second icon, allowing for a "second look" at the stimulus. The effect of "multiple looks" should be to increase both the clarity of the stimulus and accuracy of reporting it. Whether more accurate perception is due to an improved percept (Haber, 1967, 1969) or a result of Bayesian decision processes (Doherty & Keeley, 1969, 1972) is a question that has not been completely resolved, although early work suggests that clarity is not correlated with accuracy (Glanville & Dallenbach, 1929).

Under most circumstances, the effective processing time (iconic duration) is highly correlated with the latency of voluntary eye movements. Both processing time (e.g., Haber & Nathanson, 1969) and eye-movement latencies minimally have duration of roughly 250 msec (Wheless et al, 1966), depending on the stimulating conditions. Thus, processing is normally ended by the time eye movement occurs. Davison, Fox, and Dick (1973) reported an experiment in which iconic duration and eye-movement latencies were, at least partially, separated.

The Davidson et al (1973) experiment is complicated by virtue of introducing an eye movement between two stimuli. The basic situation is as follows: five letters were presented, followed by an eye movement which triggered a mask which covered one of the letters. To produce an eye movement within a short time after the letters, it is necessary to "program" the start of the eye movement before the letters were flashed. Further, a short delay was imposed on the mask to ensure that the eyes had stopped moving when the mask occurred. The latency of the eye movement was measured relative to the letters so that it was possible to determine when the eyes had moved and therefore to eliminate any trials on which the eye movement had occurred before the letters. In a control condition without eye movements, it was shown that the mask had a local effect; i.e., a mask in the fourth position of the display masked primarily the fourth letter. By contrast, if an eye movement occurred between the letters and the mask, the S was able to report the letter in the position where the mask occurred but some other letter was masked. For example, a mask in the fourth position might not mask any letter if the eye movement was from right to left and would mask the second letter if the eye

movement was from left to right. Furthermore, masking was less effective in the eye-movement condition, possibly implying that sensitivity of the eyes was reduced for a brief period after the eye movement.

In addition to naming the letters in the display, the Ss were also asked to identify the position of the mask. Somewhat paradoxically, the Ss almost never missed the true location of the mask. (This is also true for the letters, but no systematic observations were made.) For example, they were able to say that the mask occurred in the fourth position even though it affected some other letter.

These data suggest that the icon possesses many retinal properties, but it is probably not retinal since dichoptic masking can be obtained under similar conditions (Barry, 1974; Schiller, 1965; Turvey, 1973). The picture emerges that the icon is undoubtedly cortical, yet is without benefit of other information such as the fact that the eyes have moved. The eye-movement information must be integrated somewhat later in analysis. The data also show that an eye movement does not "erase" the icon; the Davison et al (1973) experiment, however, involved a "trick" because the letters were presented near the end of fixation rather than the more typical presentation at the beginning of a fixation.

The icon exists without benefit of the information that the eyes have moved. Moreover, the icon seems to be "protected" during and after an eye movement, such that a subsequent stimulus may be suppressed (Matin, Clymer, & Matin, 1972), which would account for the reduction in the strength of masking observed by Davidson et al during the eye-movement condition. An eye movement "moves" the iconic representation with respect to the physical world. This finding is consistent with the interpretation that the iconic representation is the basis of processing, not the physical availability of the stimulus.

It seems clear that any specific statements about the relation of the icon to eye movements will depend critically on the duration of the icon. For example, Haber and Hershenson (1973) assume that the icon lasts for no more than $\frac{1}{4}$ sec, which is also the minimum time for an eye movement. Thus, the icon will always have disappeared *before* an eye movement can occur. Some subsequent work using the basic Davidson et al procedure shows that Haber and Hershenson's suggestions cannot hold. Doerflein and Dick (1974) required Ss to move their eyes between presentation of an eight-item display and a bar marker. They found that even when the eye movement occurred 400-500 msec after the display, the S had shifted the display in the direction of the eye movement. Thus, the shift of the display is not constrained by the duration of masking, nor is the icon erased by a subsequent eye movement. It is not possible to determine from the Doerflein and Dick

data the maximum delay at which a shift no longer occurs. Nevertheless, the data suggest the existence of a fairly long icon which persists through an eye movement. Of course, the work discussed here barely scratches the surface of this highly important question.

FUNCTION OF THE ICON IN RELATION TO OTHER MECHANISMS

To this point, we have examined issues related to the properties of iconic memory, its contents, and the variables that will influence the contents. We now turn to work in which the emphasis is on the functional aspects of iconic memory; i.e., how material is transferred out of iconic memory and how iconic memory relates to other systems.

The Function of the Cue

In his original experiments, Sperling compared the accuracy on full report with accuracy on partial report. His results indicated that the proportional accuracy for partial report was superior to that for full report when the cue occurred shortly after the display, but there was little difference for those two types of report when the cue was delayed 1 sec. A number of investigators subsequently have used the measure as an indication of selection and as a measure of decay (Clark, 1969; Holding, 1970; Turvey & Kravetz, 1970; von Wright, 1968, 1970).

Dick (1971a) argued that there were two problems associated with the measure. First, if partial-report and full-report trials are run separately in the experiment, partial report will show decay but full report will not. If, however, the full-report conditions are randomly mixed with the partial-report conditions, then both full report and partial report will show a decrease in accuracy (Dick, 1967). The reason full report decays in the mixed case is the time required to analyze the cue (Appleby, 1972), time which cannot be used to process the display. Furthermore, there is a second problem involved in this kind of procedure, and it contains, perhaps, a more serious confounding. Under partial-report conditions, Ss are required to make far fewer responses than they are under full-report conditions. It is known that "output interference" strongly influences the accuracy of a response with respect to the position in the response sequence (Tulving & Arbuckle, 1963). The second response in a series is typically less accurate than the first, the third less accurate than the second, the fourth less accurate than the third, and so on. Thus, a simple comparison on accuracy for full and partial report is guaranteed to give partial report the edge, because, on the average, it will have less output interference. Dick (1971a) analyzed a number of partial-report data in terms of

accuracy as a function of response position. In all cases analyzed, full-report accuracy was higher than partial-report accuracy for comparable response positions. At least for the experimental conditions examined (all involved verbal report), the data do not provide any evidence for any sort of mechanism in which the S can select some parts of the contents of iconic memory to analyze in preference to other parts. Furthermore, output interference effects were independent of decay.

Other data show that the change in the benefit of partial report over delay is a function of model of response as well as other task parameters. These data simultaneously provide some hints about underlying mechanisms of perceptual processing. Von Wright (1972) examined the benefit of partial report as a function of both written and verbal report. In addition, he compared conditions in which full and partial report were mixed together vs the two run separately. Von Wright was able to obtain data which replicated both Sperling's (1960) and Dick's (1969) results. The difference between full and partial report was much greater when Ss wrote their responses than when they spoke them. Furthermore, the Ss claimed that they used different strategies for the two modes of report. When writing, Ss claimed that they "visualized" the stimuli, but when verbalizing, the Ss reported that they did not feel that such visualization was of any help.

Von Wright did not comment on the possible role of output interference, in part because the order of responses is often lost when Ss write their own responses. One cannot be sure that a S will record his responses from left to right any more than Ss will report verbally exactly from left to right. Some of our unpublished data suggest that the same output interference problems that exist in written report exist in verbal report. In fact, I doubt that output interference is a response-based effect.

Despite the possible confounding of output interference, there is no question that Ss have more information available than they can report. Nor is there any question that the S's behavior reflects the operation of selection. The heart of the issue is: How does selection operate? The issue has not been resolved, and it is likely that a single answer is not forthcoming. Indeed, the locus of selection may depend importantly upon task parameters, as von Wright (1972) has suggested. The data discussed earlier suggest a reasonable distinction between single- and multi-item cueing procedures. Thus, a bar marker might allow a S to select an item out of iconic memory but a semantic position cue might force selection from short-term memory.

Subject Bias. In an iconic memory experiment, Ss do not perform equally well on all members of the display or equally well between rows, for that matter.

Adult Ss arrive in the laboratory with highly engrained biases which have accrued from their years of reading experience. In the absence of instructions, Ss will report a two-row display from left to right and from top to bottom (Dick, 1967). This report bias complicates the examination of decay from iconic memory but does not invalidate the findings of decay. Holding (1971) asked Ss to guess which of the three rows they would be asked to report before each trial. He separated the data into two categories: those trials on which the S anticipated correctly and those on which he anticipated incorrectly. Holding reported that more decay was found for the incorrect anticipations than for the correct ones. Results consistent with this finding were also reported by Dick (1967). Although Holding interprets his data as evidence against iconic memory, the data are perfectly consistent with the notion that iconic memory has a serial output; the last items out of iconic memory should show greater influence of decay than the initial items (Dick, 1967).

Short-Term Memory Selection. Experiments dealing with the order of report in short-term memory show that Ss can easily order their responses in terms of parts of the list. In one such experiment, Posner (1964) presented Ss with auditory lists of eight digits at a rate of presentation of either 30 or 96 digits/min. Ss were instructed either to recall the digits in the order presented or, in a separate condition, to recall Items 5-8 and then 1-4. The results indicate that the first half recalled show the highest accuracy. The relatively slow rate of presentation in comparison to iconic studies would seem to rule out iconic-like effects on the order of recall of the items. A number of other experiments have shown similar effects when order of recall is manipulated both in tachistoscopic recognition (Bryden, 1960; Bryden et al, 1968; Dick & Mewhort, 1967; Scheerer, 1972, 1973a) and in serial presentation (Anderson, 1960; Howe, 1970, Chap. 3; Epstein, 1969, 1970). Although one might argue that auditory presentation as used in Posner's study might have different temporal properties from vision, it is precisely the point that many of the response characteristics are not due to properties of iconic memory but to short-term memory. The suggestion is that the iconic analyses are stable and fixed, unaffected by the cue; the cue directs transfer of items out of iconic memory.

Attention. The suggestion that the cue directs transfer of items from iconic memory to short-term memory is another way of suggesting that the cue serves to switch attention. This hypothesis has been explored in some detail for visual probes by Eriksen and his colleagues (Eriksen & Colgate, 1971; Eriksen & Collins, 1969; Eriksen & Hoffman, 1972a, b; Eriksen & Lappin, 1967; Eriksen & Rohrbaugh, 1970b). The general result of these investigations has been to provide evidence for three factors: (a) cue

processing time, (b) attention switch time, and (c) decaying information. In order for the S to respond appropriately, it is necessary for him to process the cue to find out which letter he should report; the cue processing, of course, will require some time. If he has not already done so, it then is necessary to switch processing to the requested letter so that he can report. The switch will also require a small amount of time. Thus, we have two factors which will take time that adds up to several hundred milliseconds. If this time must be consumed while the icon is available, then less processing can be carried out on the stimulus array than if the cue processing had occurred before the display.

Processing Interference

A number of investigators have been concerned with the question of whether processing is serial or parallel. Various sets of data exist which support one side or the other. It is probably the case, at least in retrospect, that the question was ill formed (Garner, 1970). In tachistoscopic recognition work, typically a number of items are presented simultaneously but the response is sequential, whether verbal or written. Thus, the real question is not whether processing conforms to one or the other, but, rather, how and when does processing change from a spatially parallel process to a serial process.

In the preceding section, we suggested that the cue has an influence on the order of transfer of items out of iconic memory, but the cue has no direct influence on the icon itself. Thus we have the rather bald assertion that transfer is serial but we have said nothing about the way processing is carried out in iconic memory. (Note the contrast of this view with that of some investigators who seem to imply that no processing occurs in iconic memory, that iconic memory is simply a buffer which stores the results of some prior processes until additional processing can be carried out.) In contrast to a serial transfer mechanism, there is clear evidence for parallel events, especially in detection tasks (Eriksen & Spencer, 1968; Estes, 1972).

Use of a cue is only one of the ways that iconic memory has been studied; a second method involves masking. Several types of masking effects occur. For example, in a multi-item tachistoscope display, accuracy is not consistent across the display; items on the end or extreme positions are generally reported more accurately than items in more central positions. Woodworth (1938) suggested that the phenomenon was due to "spatial masking" created by the adjacent letters. This type of explanation has been employed by subsequent investigators even though it has never been clear what sort of interference is involved or whether this interference actually involves masking.

Nevertheless, there is ample evidence to suggest that simultaneously presented items can interfere with

one another. For example, Eriksen and Lappin (1967) found that a line indicator which designated one relevant pair out of two did not yield performance as good as did presentation of the relevant pair alone. (See also Eriksen & Hoffman, 1972a, b; Eriksen & Rohrbaugh, 1970b.) One implication of this interactive effect is that the underlying mechanism must consist of parallel processes which are relatively independent of acuity factors (Harcum, 1964) and probably are not due to metacontrast (Townsend, Taylor, & Brown, 1971; cf. Haber & Standing, 1969b).

A second type of masking is backward masking. The way in which a mask can affect a display has been the subject of some controversy (e.g., Scheerer, 1973b), with the two major views being a degradation hypothesis and an interruption hypothesis. Spencer (1969) has provided some data relevant to connecting the two hypotheses in the context of visual cue experiments. He compared a flash mask with a pattern mask under similar conditions. The cue occurred simultaneously with the display or 100 msec after the display; the relation of the cue to the mask was either simultaneous or with the mask following at various delays. The pattern mask was more effective than the flash mask but of critical interest is the effect of delaying the cue by 100 msec. The result was to add at least 100 msec to the temporal range over which the pattern mask was effective. Performance for the delayed cue was lower than it was with the simultaneous cue, a finding which would be expected as a result of decay. However, pattern mask performance for the delayed cue was above chance, which indicates that the Ss processed some of the items during the delay and occasionally one of these items was requested. The data suggest that for any delays >150 msec, the pattern mask eliminates further processing of all unprocessed items (also Spencer & Shuntich, 1970). The above-chance performance for the delayed cue suggests that the S processed some of the items, most simply interpreted as a serial mechanism, although one could develop a hybrid limited-capacity parallel model. Whichever model one prefers, it is clear that the mask is effective in a way different from the influence of the cue.

The degradation of the target stimulus by a mask is probably a spatially parallel process (Neisser, 1967). If the delayed patterned mask stops processing, as Spencer suggests, then we have a second spatially parallel mechanism inasmuch as all unprocessed items are affected equally and lost. By contrast, identification of items in the array appears to occur in a serial manner (Neisser, 1967; Sperling, 1963). The data from partial-report experiments can also be used to infer serial processes (Clark, 1969) under some restrictive assumptions; that is, if all of the items were processed simultaneously, there would be no effect of delaying the cue unless the S delayed processing until

the cue occurred. Spencer's data suggest that processing is not delayed, as does the difference in rates of decay for different rows (Dick, 1967). Thus, both a strict parallel mechanism and serial mechanism must be involved in processing.

Two experiments (Dick, 1972b) were designed to examine the relation of two factors to accuracy: (a) visual interference (masking), and (b) decay of information. First, if order of processing is a crucial variable, most of the effect should be observed within a single row and less so between rows. Second, if iconic memory factors are involved, then these effects would be observed as a change in accuracy over time. Finally, if spatial masking is involved, then one should be able to demonstrate it through presentation of a masking stimulus at several delays. A three-row display consisting of four letters per row was used. The effect of a masking stimulus was measured by applying a mask to part of the three-row display and having the S report either a masked or an unmasked row as indicated to the S by an auditory cue.

The results provide evidence for three points: the effect of the amount and delay of masking and the effect of delaying the cue. In general, if two rows of the display were masked, accuracy of report was higher for the remaining row than if only one row was masked. In turn, masking one row produced higher accuracy than did no masking. The data show that the masks did not function as a cue. Increasing the delay of the mask uniformly decreased accuracy for unmasked rows. By and large, the effect of having material available but not required in report was large and consistent in decreasing level of accuracy. With respect to delay of report (or loss of information from iconic memory), there was evidence of reduced accuracy, but this effect was not nearly as large as the accuracy reduction due to unmasked rows.

The differential effects of masking unreported rows and delaying the cue support the idea of two separate mechanisms. The mask seems to be having its effect at a level in which processing of the input is still in a spatially parallel mode. If this were not the case, the unreported material should have no effect on the level of accuracy of the reported material. [See also Eriksen and Hoffman (1972b), Eriksen and Rohrbaugh (1970b), and Mewhort (1967), who found that the familiarity of the unreported row influenced accuracy of the reported row.] The cue, by contrast, provides evidence that some aspects of processing are serial. If processing were entirely parallel, delaying the cue would have no effect. Thus, the most reasonable explanation of the effects of the cue seems to be in terms of switching attention or changing the order of transfer of groups of items from iconic memory to short-term memory. This explanation is consistent with the finding that partial report is not better than full report (Dick, 1971a). In partial report, it is likely that the S will begin to process the wrong row on some

occasions (Holding, 1971); the cue allows him to switch to the correct row (if necessary), but a switch would require time (Broadbent, 1958) or processing capacity (Mewhort, Thio, & Birkenmayer, 1971). If a switch is not necessary, the S would not have to interrupt transfer, with the result that decay might not have an effect before transfer is complete. This explanation is consistent with the prediction that, if the S can make the switch in advance, performance will be higher; data from precueing studies tend to support this prediction (Dick, 1969; Eriksen & Colgate, 1971; Eriksen & Collins, 1969; Eriksen & Hoffman, 1972a; Eriksen & Rohrbaugh, 1970b).

The Relation of Iconic Memory to Processing Capacity

Several experiments have examined the relation of iconic memory to short-term memory. In a preliminary experiment, Turvey (1966) asked Ss to retain five letters, five digits, or five binary digits while performing a Sperling task involving letters. There was no effect of the material held in memory on performance of the partial-report task, but there was an effect in the reverse direction, i.e., the partial-report task affected the material held in memory. A much larger percentage of recall errors occurred when letters were held in memory than when digits were held in memory. Iconic memory analysis does not appear to be influenced by subsequent memories (Wickelgren & Whitman, 1970), but the results of that analysis may be affected. This interpretation is supported by Spencer (1971), who presented single letters and varied information load by manipulating the number of possible alternatives; processing time was controlled by use of a mask. Spencer showed that performance asymptoted at 125 msec independent of information load. Increasing information load served to reduce accuracy, but did so without changing the shape of the masking functions. These data show that masking operates while the input is still in a parallel mode of the system, but the information load must have its effect after masking.

Doost and Turvey (1971) examined the effect of processing capacity on iconic memory in more detail. They carried out various manipulations of tasks using the partial-report paradigm as an intervening task. In one case, the S was presented with a CCC trigram. Different conditions show little effect on partial-report accuracy, according to whether the trigram was recalled by the S, whether it was merely present and not required for recall, or whether it was absent, as in the partial-report condition alone.⁵ The trigram recall condition was uniformly lower in accuracy but not statistically different from the other condition. There was, in all cases, however, a significant decline in accuracy with delay of the cue and an interaction of

delay with condition. A second experiment involved a speeded classification task in which Ss were asked to classify a single letter as either a vowel or a consonant. The visual display and the single orally presented letter occurred together. The S responded as fast as he could in classifying the single letter; then a postexposure delay cue occurred, indicating to the S how to report the visual display. Here, too, the results show no statistical effect of the classification task on accuracy of partial report, although performance was slightly lower than in control conditions. In a third experiment, the selection criterion for the partial report task was that of shape instead of spatial location as used in the other two experiments. The speeded classification task was again used, and in this case there is no hint of a difference due to classification or a decline in performance as a function of delay of the report cue as compared to control conditions.

Doost and Turvey (1971) reached the conclusion that iconic memory is independent of processing capacity. Doost and Turvey (1971) do not describe the theoretical model they had in mind, although Turvey (1966) seems to imply that iconic memory is an epiphenomenon. The point contained in the Doost and Turvey paper is that iconic memory itself does not take up any central processing capacity for its maintenance. There are some criticisms that can be leveled at their studies. First, the believability of their arguments depends upon the acceptance of the null hypothesis. Second, the requirement of remembering three alphanumeric items would not require all of short-term memory capacity. In full-report tasks, Ss seldom report more than four or five items anyway. Thus, if one filled short-term memory with material, performance on an iconic task would be affected. Third, the timing of the intervening task was such that the S could complete the analysis necessary in their Experiment I before the stimulus display of the partial-report task was presented. Varying the timing and increasing the amount of material might not produce the same results if short-term memory is filled when the new material arrives.

In one of the Doost and Turvey (1971) experiments, the capacity used by the to-be-remembered item was in terms of maintaining the item and not analyzing it for its content. In the other two, some analysis of the additional item was required. An experiment by Mewhort (1972) indicates a complex interaction between the time of arrival of the extraneous material and the familiarity of the visual display. Based on previous work (Mewhort et al, 1969), Mewhort assumed that the contents of iconic memory were scanned to be transferred into short-term memory. Because it had been shown previously that familiar materials are transferred more rapidly than unfamiliar materials, the familiar materials ought, for a short period of time, to take up more space in

short-term memory than would unfamiliar materials. Subsequently, however, familiar materials can be recoded or chunked to occupy less space. Thus, the amount of short-term memory capacity required for familiar vs unfamiliar materials ought to vary as a function of the time since presentation; that is, the space required by familiar materials ought to decline with passage of time since presentation. In his experiment, a row of letters was presented, and either immediately or after 1 sec, a row of digits was presented. The exposure duration for both types of materials was 100 msec. In addition, the letter sequences were either of fourth-order approximations to English or zero-order approximations. At the termination of the digit display, the S was required to report as many of the letters and digits as he could. The results clearly fit the hypothesis of differential utilization of short-term memory capacity. Familiar materials, indeed, require relatively more capacity immediately after presentation but less capacity than unfamiliar sequences after 1 sec. As the presentation of the digits was delayed, letter accuracy increased for both fourth-order approximations and zero-order approximations. More importantly, however, the accuracy on numbers showed an interaction. There was a small improvement in digit accuracy as a function of the delay if the preceding items were zero-order approximations. There was a much larger improvement in digit accuracy if the preceding items were fourth-order approximations. Indeed, at the short interstimulus interval, digit accuracy was slightly lower if the preceding items were fourth-order than it was if the preceding items were zero-order. These data then suggest that short-term memory capacity does play a role in processing visual information, but in a relatively straightforward manner. If all of the short-term memory capacity is used up, there can be no further gain in the absolute amount of information taken from the icon. This does not mean that new items cannot replace old ones, but the amount or number of items will remain relatively constant. Further, the role that short-term memory plays will also be dependent upon the type of material and how fast it can be read out of iconic memory. Finally, time will also be important, since recoding seems to take place in short-term memory and requires some amount of time to transpire.

The data on processing capacity provide information on several points. First, processing capacity need not be considered to be either visual or verbal but is a combination of both, a point that is clear in the data of Brooks (1968), who showed that two simultaneous verbal or two simultaneous visual tasks took longer than one verbal and one visual task. Second, however capacity may be filled, it does not seem to influence analyses occurring in iconic memory. This interpretation leads to the implication that iconic memory is independent of meaning or

familiarity of the stimulus. Failure to find different rates of decay as a function of varying familiarity of the stimulus is consistent with the interpretation. Third, the differentiation of processing into two modalities lends some credence to the notion expressed earlier than verbal report in single-item probe experiments and multi-item cue experiments does not necessarily examine identical aspects of the system. Ss apparently are quite flexible in trading off visual and verbal capacity, depending on the processing demands.

Capacity and Rate of Processing

The general thrust for the review builds on a two-stage model; one stage is iconic memory with one set of parameters and variables, and the other is short-term memory with a second set of parameters and variables. The analyses which occur in iconic memory seem to be independent from short-term memory; the material that gets into short-term memory, however, is in part a function of the analyses which occur in iconic memory. The experimental analysis of the relations depends upon a response on the part of the S, a point so obvious that we sometimes forget it. The emphasis in the review is on identification tasks, sometimes mislabeled tachistoscopic recognition. Because of the identification characteristic of most of the experiments reviewed, it should also be obvious that one could overload short-term memory; indeed, this observation led Sperling (1960) to perform his original partial-report experiments.

Despite the positive contributions of Sperling, he managed to cloud some issues in subsequent work (Sperling, 1963). In his 1963 paper, he introduced the Baxt procedure involving backward masking. By employing backward masking, he was able to show that Ss reported an additional letter for each additional 10 msec of exposure. Here we have one of the first reports on the rate of processing of information in an identification task. The difficulty is that Sperling (1963) simply did not go far enough; he used a maximum of six letters. An inspection of his figure showing these data gives a *hint* that linearity may not hold when just six items are presented; surely the linearity will not hold, even for a practiced S, if eight or more items are presented (Mewhort et al, 1969). (Perhaps Sperling forgot why he did the 1960 work.) In general, it would seem that the rate of processing issue is rather restricted for the identification task because performance depends so heavily on the amount of space available in short-term memory. In addition, of course, rate of processing will depend upon stimulus parameters such as contrast ratios. Because of these problems, it does not seem appropriate to concentrate on finding a magical number. Rather, one should concentrate on relative rates of identification and determine if they can be

changed in any systematic way.

About the time Sperling (1963) was developing the Baxt procedure, Neisser (Neisser, 1963; Neisser, Novick, & Lazar, 1963) was developing his search task. Although this task undoubtedly places demands on processing capacity, the demand is relatively constant. The S need not remember the items (characters) he rejects, and accordingly the buildup of items in short-term memory characteristic of identification tasks is absent (cf. Eriksen & Spencer, 1969). The difference between the detection task and the identification task cannot be underestimated—exploration of the same issue with the different tasks may lead to diametrically opposite conclusions. For example, Brand (1971) and Ingling (1972) showed that category of background items in a search task influenced search rates, which they interpreted as showing that letter/number categorization could occur without naming. In contrast, Dick (1971b) measured reaction time and Nickerson (1973) measured accuracy in identification tasks. Both of these latter sets of results lead to the conclusion that letter/number categorization occurs *after* naming. From the example, it is patently clear not only that detection and identification tasks yield different results, but also that these tasks must place different processing demands on the S. Precisely what these differences may be remains an important issue to be resolved. To quote Estes and Taylor (1966), "Assumptions concerning learning and memory will be required in a detailed theoretical account of the differences in estimates of perceptual span obtained with report and detection procedures, but discussion of these is beyond the scope of the present paper [p. 16]."

"COGNITIVE SCANNING" AND ORDER OF REPORT

The preceding sections on function of the cue and processing capacity contain hints about the relation of iconic memory to short-term memory. We turn now to data that seem to be relevant primarily to the question of transfer from iconic memory to short-term memory. The basic question involved in this research is how a S converts a spatial array into a sequential-verbal response. The review is brief, but it illustrates some of the issues involved in understanding how the iconic representation is utilized.

Since the early to middle 1950s, the research on this problem has followed two theoretical orientations. One track has been based on laterality mechanisms in which it is assumed that one hemisphere is more specialized for speech and verbal behavior than the other. It is thought that right-handers will generally have speech localized in the left hemisphere. Accordingly, for right-handers, linguistically related

materials such as letters or words should be more accurately recognized in the right visual field than in the left because the right field is directly connected with the left hemisphere. Thus, differences in accuracy on tachistoscopically presented letters to either of the two visual fields can be accounted for in this way. [See White (1969) for a review of this work.] The other line of research has followed a different theoretical orientation; namely, cognitive scanning. The point of divergence may be found in Heron's (1957) work. He showed that when materials are presented simultaneously to both visual fields, the left field is more accurate. [Also, in subsequent work, many investigators (e.g., Bryden, 1960; Sheerer, 1972) have shown that alphabetic materials are better recognized in the left visual field than in the right visual field with bilateral presentation.] Heron attributed these effects to a "cognitive scanning mechanism" that normally proceeds from left to right with alphabetic materials. Thus, with unilateral presentation, the S may go from the fixation point immediately to the right and scan in the normal order for materials for the right visual field, but with material in the left visual field he must first go to the left, which is counter to the normal scanning direction. For the bilateral presentation case, it is much more efficient for Ss to begin on the left and proceed across the display from left to right. Whether or not the unilateral presentation can be explained by this mechanism is well beyond the scope of this paper (cf. Bryden, 1966a). What is of concern, however, is the elaboration of the scanning mechanisms under bilateral presentation conditions.

Order of Report

With free recall, the S will tend to report the items in a display in a left-to-right manner (Bryden, 1966b). Thus, for several possible reasons, it is not terribly surprising that accuracy on the left side of the display is better than that on the right side of the display. One of them is output interference, but this explanation can be ruled out for letter materials by two separate experiments. In one, Bryden (1960) asked his Ss to report a single row of letters from left to right or from right to left by giving them a postexposure instruction cue. He found that Ss had much more difficulty in reporting from right to left than from left to right, accuracy was lower, the latency of response was longer, Ss' introspective reports suggested that it was a more difficult task, and order-of-report scores were lower. (Order-of-report scores assess the extent to which Ss can follow the instructions by measuring the sequential nature of the responses.) At the same time, Bryden tested Ss with geometric forms. With forms, he found that Ss could report in either direction with approximately equal accuracy and similar order-of-report scores. From this experiment, it would appear that the left-side superiority for letters is not due to

order of report-output interference artifact. Rather, the effect is due to the experience of the S with the materials. Indeed, a follow-up experiment (Bryden et al, 1968) confirmed this for numbers. Numbers are almost as familiar as letters, but the order of report was somewhat more flexible.

The second experiment examining the left-side superiority on letters was carried out by Mewhort and Cornett (1972). They employed first- and fourth-order approximations to English as stimulus materials. On half of the trials, the statistical constraints were in the reverse direction. Thus, a fourth-order approximation sequence such as MOSSIAN was presented normally and on a subsequent trial might have been presented as TNAISSOM. Ss were provided with postexposure cues and asked to report these materials from left to right or from right to left. The results show that not only were the Ss better at reporting from left to right than from right to left, but also that the familiarity of the stimulus sequences was beneficial for right-to-left report only when the statistical constraints were physically organized in left-to-right orientation. This result suggests that Ss scan from left to right and then report in the order requested.

Taken together, the data of Bryden (1960; Bryden et al, 1968) and Mewhort and Cornett (1972) suggest that there is something unique about letters which almost demands that the S deal with them in a left-to-right manner. This is clearly not a neural bias as would be suggested by laterality difference, but rather a functional bias that is most likely due to specific experience with the materials. Letters are generally treated only from left to right, whereas numbers are treated both left to right and right to left (Bryden et al, 1968). Thus, it would seem that the underlying mechanism must be biased due to experience. (See also Holly & Nuismer, 1972.) Indeed, a developmental examination of left-to-right and right-to-left report with letters, numbers, and geometric forms seems to confirm this hypothesis (Dick & Loader, 1974). The bias seems to be well established empirically, but the underlying mechanism is little understood. There are, however, studies in the literature that provide some hints as to how this mechanism might work and some suggestions for further work to examine the scanning mechanism (Mewhort, 1974).

Eye Movements

The cognitive scanning theory of Heron involves a prediction about postexposure eye movements which would reflect motor overflow from the internalized scanning. Bryden (1961) has provided some preliminary data. He presented Ss with a single row of letters or geometric forms and recorded eye movements, as well as free-recall accuracy. He found that the direction of the postexposure eye movement was correlated with the mean locus of recognition.

(Mean locus of recognition here refers to the average of the ordinal positions of the items correctly reported.) The observed correlations suggest that an eye movement to the left is associated with higher accuracy on the left side and an eye movement to the right is associated with higher accuracy on the right side. Bryden also reported that there was no relation between order of report and direction of eye movement. This result is somewhat surprising but may likely have been due to (a) the small number of observations that were carried out with each of the two materials per S, and (b) the fact that free recall was used. The finding that postexposure movements are correlated with accuracy is completely consistent with the theory of Hebb (1949), in which he suggested that perceptual development is partially dependent upon motor mechanisms. Because iconic memory is uninfluenced by eye movements (Davidson et al, 1973), the correlation between the accuracy and eye movement rules out the sole involvement of iconic memory mechanisms.⁶ Additional mechanisms may include short-term memory and possibly imagery (Harnad, 1972).

Other Tasks Not Involving Ordered Report

The left-to-right bias found with ordered report (Bryden, 1960; Bryden et al, 1968; Dick & Loader, 1974; Mewhort & Cornett, 1972; Scheerer, 1972) has not been found with procedures in which the S is asked to report just one item. For example, Smith and Ramunas (1971) presented a single row of letters and asked the S to report just one of the letters using a tactile postexposure cue with systematic delays of the cue relative to the stimulus presentation. They find no bias of the left side over the right at any stimulus delay up to 2 sec. Similar results with shorter delays have been found by Averbach and Coriell (1961), Lefton (1973a), and Merikle et al (1971). Mewhort and Cornett (1972) have argued that the processing demands in the single-item report task are different from those in the multiple-report task, and Mewhort and Dick (1974) showed a dissociation between the two tasks. One cannot attribute this difference to partial-report tasks in general, however, since it can be shown that one does get a left-to-right bias in the Sperling partial-report task in which a number of items must be reported (Dick, 1967) and in serial processing on detection tasks (Shaw, 1969; Shaw & LaBerge, 1971).

The failure to find a left side superiority with a visual probe is not at all damaging to a scanning theory, but, rather, is helpful in localizing the mechanism. The findings that multiple- and single-item report tasks produce different patterns of errors is also evidence to suggest different kinds of functions involved for the two tasks. Especially when letters are presented, there is, in all likelihood, some verbal rehearsal taking place (cf. Posner, 1967).

Thus, one interpretation of the scanning mechanism is that it serves to load a rehearsal loop (Glanzer & Clark, 1964). Once such a loop is loaded, it is difficult to reverse the order within the loop (for example, reporting an auditory digit sequence backwards). The left-to-right bias normally found in tachistoscopic tasks may be due to the way in which Ss normally operate in preparing for a verbal response.

Scheerer's (1972) data would suggest that some time is needed to load rehearsal. Further, Mewhort et al (1969) have shown that the rate of processing letters depends upon their statistical constraints or familiarity. Thus, it would seem consistent to suggest that the rate at which rehearsal may proceed will differ as a function of familiarity. Other findings are consistent with this interpretation. For example, Bryden (1960) reports much lower accuracy for geometric forms than for letters. Similarly, Dick and Loader (1974) and Mewhort and Cornett (1972) have similar findings with their familiarity manipulations. It is not known, however, whether performance differences due to familiarity are a result of the loading of a rehearsal loop or the speed of rehearsal, or some combination of both.

SUMMARY AND CONCLUSION

Several general issues were raised in the introduction. Two of these involved the issue of how iconic memory was coded and what the contents might be. The answer appears to be that iconic memory is uncoded and appears to be a kind of sensory memory which decays over time. The data that bear on this issue include the following: (1) manipulations of familiarity apparently do not affect the rate of decay; (2) the contents of short-term memory do not influence the processing in iconic memory; and (3) it is only physical dimensions of the stimulus which are lost, not learned dimensions. Although iconic memory appears to be a sensory process, it differs from retinal mechanisms in some important ways. For example, given some threshold amount of energy, further manipulations of energy in the form of luminance or duration manipulations do not appear to affect rate of decay from iconic memory. Further, although iconic memory demonstrates an analog of Emmert's law, it is probably cortical in locus, as evidenced by dichoptic masking (Turvey, 1973). Iconic memory research creates the impression that the icon is a relatively inflexible and fixed mechanism that is analogous to a "neural echo." As such, it should probably not be considered a cognitive process.

The relation of iconic memory to other mechanisms is more difficult to ascertain. Two short-term memory mechanisms, one verbal and the other visual, have sometimes been suggested to account for the data. The existence of the verbal short-term memory has

been well established; however, the existence of a visual short-term memory is somewhat more inferential and certainly should be the target of further research, particularly its potential relation to work on imagery. At present, it does not appear to be necessary to suggest two separate short-term memory mechanisms. In the present approach, we have opted for a single short-term memory which has both visual and verbal properties.

Independently of one's theoretical position, the role of short-term memory may well vary as a function of the processing demands. When a sequence of verbal responses is required, verbal behavior is intimately involved. When a single verbal response or written responses are required, the involvement of short-term memory is lower than in the former case. However, short-term memory does not appear to have a direct influence on the processing within iconic memory.

Alternative Interpretations of Iconic Memory Data

Implicit in the review is the assumption that iconic memory serves as a useful concept. Recently Holding (1970, 1971, 1972) has questioned whether it is necessary to postulate such a mechanism. The data he presents in favor of his "aniconic" view are the following: (1) a failure to find a benefit of partial report; (2) guessing strategies on the part of the S which influence the amount of decay obtained; and (3) a failure to find decay with unfamiliar material. In fact, none of these data are at all damaging to the iconic view. Von Wright (1972) has clarified the benefit of the partial-report issue by showing the specific conditions under which it is obtained. Furthermore, the presence or absence of the benefit of partial report does not bear on the issue of decay (Dick, 1971a). With regard to the guessing strategies of the S, one would expect differences in decay between rows under a serial transfer to short-term memory (Clark, 1969). The longer an item remains in iconic memory before being transferred, the more likely it is to decay. Finally, the finding that performance is low and does not show decay with unfamiliar material does not contradict the concept. Using the Sperling paradigm, Dick (1967) also failed to find decay with unfamiliar materials. However, both Holding's and Dick's experiments involved the use of multiple-item report. Dick and Loader (1974) used the same stimulus materials as Dick (1967), but employed the Averbach and Coriell (1961) procedure of requiring report of a single item. In this case, decay was observed. As noted earlier, there is a difference between single- and multiple-item cueing which is apparently manifested in terms of the locus of the effect of the cue relative to iconic and short-term memory. Single-item cues appear to operate within or closer to iconic memory than multiple-item cues (Mewhort & Dick, 1974). Further, the failure to obtain evidence for iconic memory clearly does not

rule out its existence (Dick & Loader, 1974). Although Holding's data might be embarrassing to some interpretations of iconic memory, his data are clearly not embarrassing to all.

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NOTES

1. The discussion in this paper is primarily on visual processes, but we would be remiss if we failed to point out that the auditory and tactual modalities also show evidence for similar processes (Bliss, Crane, Mansfield, & Townsend, 1966; Efron, 1970; Efron & Lee, 1971; Hill & Bliss, 1968; Massaro, 1971).
2. In many ways, the afterimage-icon differentiation is similar to the differentiation between afterimages and the aftereffects originally described by Gibson (1937) and Köhler and Wallach

(1944). Ganz (1966) attributes the aftereffect to the same peripheral mechanisms that mediate afterimages. More recently, however, aftereffect studies have been carried out in the context of specialized cortical "detectors" (e.g., Blakemore & Sutton, 1969). Campbell and Maffei (1970) have compared visual evoked potentials with psychophysical judgments on the visibility of gratings. Their results show remarkable agreement between the two measures. Furthermore, Maffei, Fiorentini, and Bisti (1973) have recorded cortical cells before, during, and after adaptation to gratings. These data suggest rather strongly that simple cells are the major site of adaptation aftereffect in the cat. These kinds of data provide evidence that the aftereffect is not peripheral and it certainly is not a peripheral afterimage. The relation between the aftereffect and an icon is not clear, although it seems to be consistent to suggest the possibility that the two phenomena are mediated by the same mechanism (e.g., Dick, 1972a; Parducci & Brookshire, 1956).

3. From all indications, it would seem to be more consistent to use stimulus onset asynchrony (SOA) as the temporal measure instead of interstimulus interval (ISI). When SOA is used on data collected with homogeneous double pulses of light, the data are far more consistent between experiments than when ISI is used (Boynton, 1972). The procedure also appears applicable in perceptual experiments. An example of the difference can be taken from any "processing time" experiment (e.g., Haber & Nathanson, 1969; Mewhort et al., 1969) in which the processing time is measured from the initiation of the target stimulus and not from the termination. If one were to use termination of the target as in ISI, the results would be far more inconsistent and even misleading, because some processing occurs while the stimulus is physically present. Unfortunately, almost none of the iconic experiments are described in terms of SOA but certainly much of the variation in the asymptote of the decay curves can be attributed to changes in SOA

while ISI remains constant. In other words, processing time has been manipulated accidentally even while holding ISI constant.

4. Approximations involve using various structures of printed text. Zero-order sequences are generated using each of the 26 letters with equal probabilities. First order follows the letter frequency in printed text; second involves bigram frequencies; third order, trigram frequencies, and so on for higher orders.

5. The reader may wish to note that the first and third figures were reversed in the original publication.

6. There is basic conflict between the results of Bryden (1961) and those of Davidson et al (1973). Bryden's data suggest that the eye moves independently of the image, whereas the Davidson et al work suggests that the image moves with the eye. There is no resolution available; all that can be done is to point out differences in the two experiments. First, Bryden simply measured the first movement after exposure, whereas in the other case the eye movement was preprogrammed. Second, the stimulus characteristics differed, i.e., size, spacing, and number. Although other factors are more likely explanations, the stimulating conditions could have an effect. Third, some "slippage" is possible, as was observed in the Doerfflein and Dick (1974) work. (See also Cornsweet, 1970). The latter work was done with smaller stimuli than used by Davidson et al. Fourth, timing of the eye movement could be a factor, although Bryden (personal communication) suggested that the eye-movement latency was on the order of 200 msec. Presumably a resolution of the conflict might be reached through some combination of these factors. Finally, it is possible that postexposure eye movements reflect mechanisms of verbalization and visual imagery (e.g., Harnad, 1972); note that this explanation is quite different from the one offered by Bryden (1961).

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