(*12*). In 10 of 12 paired MRF samples collected, the concentration of protein during REM sleep was significantly higher than that during awake periods (paired t-test $= 3.94$, $P < .001$). Furthermore, the increases of hippocampal proteins were always associated with increases in REM sleep. These results are consistent with the possibility that neuronal activity in the MRF and hippocampus during REM sleep is associated with high concentrations of extracellular proteins. These cyclic changes may simply reflect an increase in cell firing, which generally increases in REM sleep (*13*), or may indicate a special function of the proteins related to awake and sleep states.

An essential question concerns the source of the perfusate proteins. These proteins might be released from synaptic endings in a manner similar to that for dopamine-β-hydroxylase (*5*) or other products of the exocytosis process. Polypeptide modulators or neurotransmitters may be present. Alternatively, the proteins may be general secretory products of neurons or glial cells. In view of the amount of protein obtained, highly active synthetic processes seem implicated. These proteins probably arise from a variety of sources. The significant point, however, is that the protein concentrations vary in relation to REM state. Our studies provide further evidence that the push-pull cannula technique is well suited for the examination of the brain's extracellular environment. This procedure should further our understanding of the neurochemical basis of behavioral states.

R. R. DRUCKER-COLÍN*
C. W. SPANIS†
C. W. COTMAN
J. L. McGAUGH
*Department of Psychobiology,
School of Biological Sciences,
University of California,
Irvine 92664*

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 * Permanent address: Departamento de Biología Experimental, Instituto de Biología, Universidad Nacional Autónoma de México, México 20, D.F. Send reprint requests to R.R.D.-C. at this address.
 † On sabbatical from the University of San Diego, San Diego, California 92110.

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Meaning in Visual Search

Abstract. *Viewers briefly glimpsed pictures presented in a sequence at rates up to eight per second. They recognized a target picture as accurately and almost as rapidly when they knew only its meaning given by a name (for example, a boat) as when they had seen the picture itself in advance.*

When we look around, our glance shifts rapidly from point to point. The average fixation lasts a mere 1/3 second. Moreover, when the observer is moving through an unfamiliar environment, each such glance may contain something new. We know that when novel scenes (pictures) are viewed at that rate, half of them do not even look familiar a few minutes later (*1*). Each glance is thus too brief to assure memory for what is seen. What other function (*2*) might such brief fixations serve? When the viewer can anticipate either what is important to see or what he is likely to see, a brief glimpse may be sufficient to confirm or refute that expectation.

Two questions were addressed in the study reported here. (i) Can an observer detect an expected scene even when it is presented so briefly that it would not otherwise be remembered? (ii) If so, what sort of advance information about a scene is required for the observer to spot it? If a viewer knew exactly what the target of his search looked like, he might select it by making a direct visual match. However, if he had only general information about the target (its meaning), each potential target would have to be recognized and categorized before selection. Such a search might be expected to proceed more slowly and less accurately than one based on visual appearance per se (*3*). In the study reported here observers were able to

pick out an anticipated scene from a set of others presented at rates even higher than those of normal eye refixations, rates at which memory for unanticipated scenes is very poor. Even more surprisingly, foreknowledge of meaning in the form of a general name permitted as accurate and almost as rapid selection as foreknowledge of exact appearance. These results suggest that we can scan our environment in brief glimpses, looking not only for particular visual patterns, but for their meanings.

A succession of rapid glances around the environment was simulated by presenting observers with a sequence of photographs of various scenes and objects (*1*). One practice and eight test sequences of 16 color pictures were shown on an L-W cine projector to two groups of 24 college students. The observer was instructed to look for a particular picture; if he saw it, he responded by pressing a lever that stopped the projector. In one group, the observer was shown the target picture before viewing each sequence. In the other group, the observer was only given a name for the picture he was to look for (for example, a boat, two men drinking beer, a child and butterfly). The names were brief descriptions of the main objects or events in the scene; colors and shapes were never specified directly. In all other respects, the procedure was identical for both groups.

Each observer viewed the practice

sequence at a rate of 250 msec per picture and two of the eight test sequences at each of four rates: 125, 167, 250, or 333 msec per picture. The order of rates was permuted across observers.

The target picture was the ninth, tenth, or eleventh picture in the sequence. For each group of 24 observers, the four orders of rates, two different orders of pictures, and three orders of target positions were factorially combined.

The upper curves in Fig. 1 show the proportion of correct responses to the target in either group at each rate. Each point is based on 48 trials. Errors for both groups were rare except at eight pictures per second; the difference between the groups was not significant. Errors were of two kinds: misses (0.07 of trials) and anticipations (0.05). The false alarm rate per picture, estimated by dividing the proportion of anticipations by the average number of pictures before the target, was less than 0.01. Most of the misses (0.77) occurred at the highest rate of presentation, whereas anticipations were equally likely at all rates. The overall mean response time, measured by the elapsed frames between the onset of the picture and the observer's response, was 531 msec for the picture target group and 563 msec for the name target group ($P < .05$, Mann-Whitney); the difference was in the same direction at each of the four rates.

To detect a target defined by its meaning rather than by a specific visual pattern, the observer presumably had to identify each scene (4). Since more than 70 percent of the targets were detected with a 125-msec exposure, the implication is that 70 percent would also be identified when the observer was not searching, but was simply looking at the pictures. One might expect identified pictures to be remembered, since several experiments have demonstrated that memory for pictures is remarkably accurate (5). However, in those experiments pictures were presented for at least 1 second each.

Memory for the pictures used in this study was measured in an earlier study (1) by giving a yes-no test of recognition memory immediately after each sequence. The observer watched the sequence but did not look for a par-
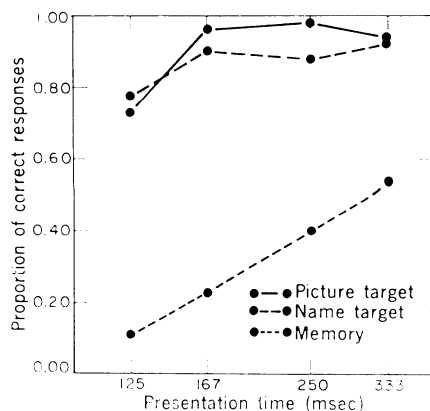

Fig. 1. Detection probability in two target conditions as a function of the rate of presentation (logarithmic scale). Recognition memory for the same pictures, measured in an earlier experiment (1), is shown for comparison.

ticular picture. The results, omitting the easy-to-remember last picture in each sequence and corrected for guessing (0.03 false yeses), are shown in the lower curve of Fig. 1. Each point is based on 960 responses.

The difference between detection and memory is striking and highly significant. The low probability of memory under conditions of presentation that allow efficient detection by name implies that many of the pictures, although briefly identified, are immediately forgotten. One's excellent memory for pictures evidently requires not only identification but something else as well—presumably a further period of consolidation. For the pictures used in this study, the median exposure duration required for identification was less than 125 msec, whereas the median duration needed for retention was more than 300 msec (6).

To return to the questions posed at the beginning, one does not need to know exactly what a thing will look like to detect it in a ⅓-second glimpse. In fact, knowing the exact appearance of a target was little better than knowing only its general meaning, which suggests that a scene is processed rapidly to an abstract level of meaning before intentional selection occurs (7). Unselected scenes, although momentarily understood, will be forgotten unless there is uninterrupted time for further consolidation. The ⅓-second length of an average glance seems to be a compromise between the need to scan the

environment rapidly for significant objects or events to which one will immediately respond, and the need to retain some knowledge of what one has seen.

MARY C. POTTER

Department of Psychology, Massachusetts Institute of Technology, Cambridge 02139

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7. A "meaningless" stimulus, such as a nonsense figure produced by constrained random processes, is one with an impoverished abstract interpretation. Although such patterns may be easy to distinguish when presented side by side, they all mean "the same thing." If selection is based primarily on meaning, it is no suprise that such figures are difficult to recognize as familiar unless they happen to look a little like a real object. How initially meaningless patterns such as x-ray photographs and micrographs come to acquire distinctive meaning has been considered by E. J. Gibson [Principles of Perceptual Learning and Development (Appleton-Century-Crofts, New York, 1969)].
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