it may have, is clearly active. In the case of static imagery, there have been no published studies concerning the scanning hypothesis formulated above: *do good visualizers scan their images more than poor visualizers?* Two experiments were conducted to answer this question.

The first study (Marks, 1972b) examined the eye movements of good and poor visualizers, defined in terms of both VVIQ score and accuracy of recall of pictorial material, during the imagery and recall phases of the picture-memory task. These data were collected in the second of the picture-memory studies outlined earlier in this chapter. The subject was seated 40 inches from a screen which gave a stimulus area of $50° \times 36°$. Electrodes were attached to allow bipolar recordings of horizontal and vertical components of the electro-oculogram (EOG) on a Beckman polygraph. Subjects were told the electrodes were for recording "brain-waves." Through questioning at the end of the experimental session, subjects were found to have remained totally naive as to the electrodes' true function. Each subject was told to keep his eyes open at all stages of the experiment and sat with his head in a headrest to prevent head-movement artifacts. Calibration of the EOG record between trials, and the presence of a centrally placed luminous spot, visible between slide presentations, allowed an accurate estimate of "center" on the record.

The first analysis of these data was concerned with eye movement rate (EMR) during the 10-second imaging phase of the task. EMR was obtained by dividing the horizontal EOG record into half-second intervals and determining the percentage of these which contained a movement of greater than 2° visual angle. Mean EMRs of good and poor visualizers for the two kinds of stimuli are shown in Table 7.

Within-subjects variability was extremely large and thus for analysis of variance, within-cell variance was estimated by summing scores over subjects for each slide and using within-slides variability to estimate the error term. The difference in EMR between good and poor visualizers was highly

TABLE 7
Mean EMRs of Good and Poor Visualizers for Stimuli Showing Complete Scenes and Unrelated Objects

	Complete scenes	*Unrelated objects*	*Means*
Good visualizers ($N = 8$)	23.0	24.5	23.8
Poor visualizers ($N = 8$)	34.8	39.9	37.3
Means	28.9	32.2	30.6

significant ($p < .005$). *More vivid imagery was associated with relatively fewer eye movements.*

The next analysis investigated the eye movement data during recall for evidence of image-scanning. This was achieved by examining chunks of the EOG record which corresponded to questions referring to details in the periphery of the stimulus displays, e.g., Questions 1 and 4 for the stimulus shown in Fig. 1. The visual field was divided into a 3×3 matrix of areas, the central area being defined as a $2° \times 2°$ square. By examining the record of both horizontal and vertical EOG components it was possible to determine where, at any point of time, the subject's eyes were looking relative to center.

To illustrate this scoring method, consider Question 4 for the stimulus in Fig. 1 (*viz.* "Did the bottom picture show a shoebrush, toothbrush, or hairbrush?") This refers, explicitly, to the area of the display directly below center. Hence, if eye movements during imagery are like those accompanying the percept, then in answering this question by "reading-off" from an image of Fig. 1, the vertical EOG component should show a response away from center indicative of downward movement. The horizontal EOG record should not deviate from center however. A subset of 20 questions was selected, each of which had a peripheral reference point. Half of these questions explicitly mentioned the direction from center of the reference point (e.g., Question 4, above) and half did not (e.g., Question 1, above). These two types of question will be referred to as "direction" and "no direction" questions, respectively. Twenty chunks of EOG record were therefore analyzed for each subject, each chunk starting halfway through a question and ending 0.5 second before the subject's answer. For each of these segments, the percentage of noncentral eye-movement path (EMP) on the appropriate reference area was calculated. This score will be referred to as the percentage of EMP "on target." With 8 peripheral or "target" areas altogether, the mean chance rate of response was 12.5. If subjects scanned their visual images, mean percentage EMP "on target" would be significantly greater than this value. Mean scores of the good and poor visualizers for "direction" and "no direction" questions are presented in Table 8.

Analysis of variance gave a nonsignificant imagery effect but a significant effect for type of question ($p < .025$). For "direction" questions, the mean percentage EMP "on target" was significantly greater than the chance level ($p < .01$) but not so for "no direction" questions. These data suggest that if subjects scanned their images at all, they did so only when a directional cue was supplied by the experimenter. Such "scanning" behavior might more cautiously be regarded as an artifactual effect arising from the influence of the demand characteristics present in the situation (Orne, 1962).

TABLE 8
Mean Percentages of EMP "On Target" for Good and Poor Visualizers, and "Direction" and "No Direction" Questions

	"Direction" questions	"No direction" questions	Means
Good visualizers (N = 8)	28.9	13.8	21.4
Poor visualizers (N = 8)	22.6	15.3	19.0
Means	25.8	14.6	20.2

For recall episodes uncontaminated by directional cues, the result was clear-cut: *no scanning of visual images was evident.* This result is in complete agreement with the earlier observation that vivid imagery reports were associated with fewer eye movements. Subjects did not move their eyes to scan their images—they kept their eyes still.[6]

A second study examined vividness a little more closely by comparing eye movement rates during a variety of visual imagery tasks (Marks & Barron, 1972). These were characterized as "imagination," "memory," "change," and "eye movement" imagery tasks. For imagination trials, subjects were asked in three separate trials to image "a close-up view of a shark's face," a "racing-car on a bed," and "an elephant made of polished wood." For memory trials, colored transparencies of stimuli referred to in the imagination instructions were displayed for 10 seconds and subjects were told: "After each slide has been removed try to keep a picture in mind of what you have seen." For change trials, subjects were shown a slide for 10 seconds and during presentation were given instructions which involved changing in some way the image of the picture displayed. For example, one slide showed a man and dog at the top of a hill and subjects were told: "After the slide has gone, try to make the dog run down the hill and back to the man several times" (see Richardson's discussion of the controllability of imagery in Chapter 5, this volume). Eye movement trials were presented last to preserve subjects' naivity concerning the purpose of the study and subjects were told: "When I take each one (slide) away, I want you to try and reconstruct the picture by moving your eyes as you try to look at each detail. In other words, try and build-up the picture that was there by moving your eyes from one imaged detail to another." Each trial comprised a 10-second baseline period, 10 seconds of instruction and/or slide presentation, 40 seconds of imaging, and finally, a vividness rating on the earlier mentioned 5-point scale. Subjects for this study were 12 of those taking part in the previous eye movement study. Six were good visualizers, as measured both by low VVIQ score and accurate recall on the picture-memory task, and 6 were poor visualizers with opposite profiles.

[6] This result is corroborated by the recent experiments of Hale and Simpson (1970) in which a different method was employed. Instructions either to deliberately make or imagine eye movements were not found to increase the rate of discovery or vividness of visual images.

EMRs were determined for each type of imagery and its respective baseline. These were obtained by counting the number of half-second intervals containing a movement of more than 2° visual angle. Mean percentage EMRs for the horizontal and vertical components of the EOG were then calculated and the difference in mean percentage EMR between each variety of imagery and its respective baseline was obtained. Relative EMRs of good and poor visualizers for the four varieties of visual imagery are shown in Fig. 2.

Analysis of variance yielded the following results: visualizing ability (n.s., $p < .10$); imagery variety ($p < .005$); and visualizing ability × imagery variety ($p < .01$). Tests of the simple effects of the visualizing-ability factor showed that relative EMRs of good and poor visualizers differed significantly ($p < .005$) for eye-movement imagery, but for none of the other types of imagery. The tendency for EMR to be lower than baseline for imagination imagery was statistically significant ($p < .05$). As observed in the study reported above, and by Antrobus *et al.* (1964), static imagery was accompanied by ocular quiescence. There was no evi-

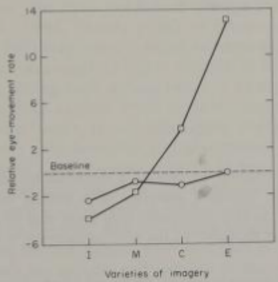

FIG. 2. Relative eye-movement rate of good and poor visualizers for four varieties of visual imagery: I, imagination; M, memory; C, change; and E, eye movement. (□, Good visualizers; ○, poor visualizers.)

dence of scanning movements. Only if good visualizers were asked to "build-up the picture that was there" by moving their eyes "from one imaged detail to another" did ocular activity exceed baseline levels. Differing sensitivity to demand characteristics may here have been the relevant independent variable. There is no convincing evidence, therefore, that the eye-movement characteristics of visual static imagery are in any way like those of visual perception—this type of imagery is associated with a minimum of ocular activity.

Eye-movement data obtained thus far permit some optimism concerning an operational classification of different imagery experiences (see the chapters in this book by Holt, McKellar and Horowitz; also Horowitz, 1970). It is well-established that dream imagery is associated with characteristic rapid eye movements (Aserinsky & Kleitman, 1955) although the precise function of these movements is unknown (Oswald, 1962). It is established also that afterimages of physical stimuli (e.g., Mack & Bachant, 1969) and of images (Oswald, 1957) move with the eyes. Eidetic images are scanned and remain still (Haber & Haber, 1964). Active "memory" or "imagination" images are accompanied by eye movements (Antrobus *et al.*, 1964; Brown, 1968). Static "memory" or "imagination" images which are perceived to be located internally, as they usually are (e.g., see Weber & Bach, 1969), are not accompanied by scanning movements (Marks, 1972b). Preliminary results suggest that under some conditions *projected* active images, which are perceived as occupying real space, *may be* scanned (Marks & Barron, 1972). Although it is not difficult to predict their characteristics, eye-movement data from the hypnagogic, hypnopompic, and hallucinatory states are urgently needed.[7]

Summary and Conclusions

The experiments reported all tackled a fundamental issue in the study of imagery: does the cognitive behavior of a person who reports vivid visual imagery differ in any observable way from that of another who reports only faint visual imagery? In the field of memory, a simple question-

[7] Of relevance here are two papers by Brady and Levitt (1964, 1966) who used optokinetic nystagmus as an objective criterion for hypnotically induced visual hallucinations of a striped drum in rotation. See also a more recent study by Graham (1970).

and-answer technique was used to test recall of pictorial stimuli. Subjects were scored *prior* to the experiment on the basis of their verbal ratings of image vividness. Good visualizers, so-defined, produced significantly more accurate recall than poor visualizers. The difference in performance was substantial, and, in one study, poor visualizers produced 36% more errors than good visualizers. Evidently, persons who report vivid imagery can utilize a source of information which may not be available to those who report imagery which is vague and dim.

Another memory study looked at the improvement in recall of verbal stimuli effected by a mnemonic device—the "mental walk." Recall improvement was significantly correlated with the amount of visual imagery reported *during* the task but uncorrelated with imagery vividness reported *prior* to the experiment (cf. Ernest & Paivio, 1969). Rather than being fixed, the ability of a person to evoke and utilize imagery is influenced by situational variables—given appropriate conditions, even so-called "poor" visualizers can evoke visual images. The potential for imagery would appear to be universal. Studies of methods by which vividness, and other imagery qualities, can be transiently or permanently altered, should continue to be fruitful.

Studies in the field of perceptual function compared the ocular behavior of good and poor visualizers, doubly defined in terms of both verbal ratings of vividness and accuracy of pictorial recall. Good visualizers made fewer eye movements than poor visualizers while "looking at" static images and no evidence of spontaneous "scanning" movements was obtained from either group. These and other data suggest that, during vivid visual images of static displays, the eyes remain still. Only if an image is *active* (Antrobus *et al.*, 1964; Brown, 1968) or *projected* (Haber & Haber, 1964; Oswald, 1962) may ocular scanning movements occur.

Watson (1928) was naturally highly skeptical of the notion of imagery: "the behaviorist, having made a clean sweep of all the rubbish called consciousness, comes back to you: 'Prove to me' he says, 'that you have auditory images, visual images, or any other kinds of disembodied processes. So far I have only your unverified and unsupported word that you have them.' Science must have objective evidence to base its theories upon [p. 75]." Given the inevitable failure of introspectionism to provide objective measures of imagery, these statements were, at that time, eminently reasonable. Modern experimental and psychophysiological techniques extend quite considerably the subject matter of the science of behavior: the private events of Watson's day are now quite public (cf. Stoyva & Kamiya, 1968). What would have answered Watson's cry for *proof* of imagery remains uncertain, but the data cited in this chapter, and in other chapters, may provide at least some of the objective evidence he asked for.