PSYCHOPHYSIOLOGY
Vol. 4, No. 3

VISUAL RECALL ABILITY AND EYE MOVEMENTS

BARBARA B. BROWN, PH.D.

Department of Psychiatry and Human Behavior, U. C. Calif. College of Medicine, Los Angeles, Calif., and Experimental Psychiatry, VA Hospital, Sepulveda, Calif.

ABSTRACT

Pursuit eye movements induced by Deckert's technique, using a moving object of specific excursion and beat frequency, were compared between active watching of the moving object and recalling the motion with eyes closed. Ability for visual imagery and incidence of its use were evaluated by questionnaires and discussion following the test procedure. Eye movements during eyes-closed recall occurred significantly more frequently in visualizers than non-visualizers. Exceptions to the relationship suggest that the occurrence of eye movements during recall do not necessarily indicate presence of visual imagery, but that oculomotor activity may be recalled independently. Eye movements during eyes-closed recall generally under- or over-estimate both excursion and timing of the original motion.

DESCRIPTORS: Visual imagery, Visual recall, Eye movements. (B. Brown)

A number of investigators have explored the relationship between eye movements and visual imagery. Some 35 years ago, Jacobson (1932) studied responses of various motor systems to passive recall of activities involving these systems, and reported that ocular convergence characteristically occurred during visual imagination. Lorens and Darrow (1962) found eye movements to be a consistent occurrence during mental multiplication and attributed them to visual imagery. Aserinsky and Kleitman (1955) observed rapid eye movements occurring in cyclic clusters during sleep in adults and believed them to be invoked in visual imagery during dreaming. In subsequent studies (Dement and Kleitman, 1957; Dement and Wolpert, 1958), evidence was presented to support the hypothesis that the rapid eye movements correspond to where and at what the dreamer was looking, a finding confirmed by Brady and Rosner (1966). Additional evidence was supplied by Berger, Olley, and Oswald (1962), who found that blind subjects who had retained visual imagery ability showed rapid eye movements during dreaming, but blind subjects who had never had, or had lost visual imagery did not show eye movements. In contrast, the studies of Gross, Byrne and Fischer (1965) in subjects with lifelong blindness and with no waking visual imagery showed recurring rapid eye movement periods during emergent Stage 1, similar to normals. Jeannerod, Jouvet, and Jouvet (1962) have reported that eye movements during "memorization" are slower and longer during recall than during active vision, and that eye movements during "memorization" are indistinguishable from those occurring during dreaming.

This investigation was supported in part by U.S. Army Engineer Research and Development Contract DA 44-009 AMC 367 (T).

Address requests for reprints to: Dr. Barbara B. Brown, Experimental Psychiatry, Veterans Administration Hospital, Sepulveda, California, 91343.

Employing a moving visual stimulus of specific excursion, Deckert (1964) found that imagining a previously-seen beating pendulum was accompanied by pursuit eye movements, and that these did not differ significantly from those recorded when actually watching the pendulum. Deckert suggested this technique as an objective measure for identification of certain types of visual imagery.

In general, studies relating visual imagery and eye movements have not reported usage of detailed evaluations of visual imagery ability. Studies which have correlated EEG changes with visual imagery have, however, generally supplied criteria used to define visual imagery. Such studies have emphasized EEG activity during recall (assumed to be visual) rather than defined ability for visual imagery or its use during recall. For example, Golla, Hutton, and Walter (1943) and Walter (1953) asked their subjects to perform mental tasks assumed to require visual imagery while both Walter and Yeager (1956) and Jeannerod *et al.* (1962) rated visual recall according to accuracy of drawings executed after recall. Slatter (1960) assessed qualities of visual imagery by asking questions after each mental task of a series and classified ability according to detail, color and movement in the recall.

The importance of visual imagery in mental and emotional activities, the difficult semantics of this topic, and the increasing emphasis on eye movement activity to monitor dream activity suggested the present investigations.

Method

Subjects

Fifty-two subjects of different ages (21 to 45), sex (equal distribution), and background were tested.

Eye Movements

A modification of the technique of Deckert (1964) was employed to quantify eye movements during active vision and recall. Electrooculograms (EOGs) were recorded by means of a Grass Model III EEG from disc electrodes, which were placed at the external canthi of each eye after the subject entered the experimental room. Subjects were not told that eye movements were being recorded, and subjects who became aware were discarded from the study. A metronome beating at 0.5 c/sec was placed eighteen inches in front of the subject at eye level. Subjects were asked to follow the motion of the metronome with their eyes, keeping the head stationary, and sixty seconds later they were asked to close their eyes, relax, and to recall the metronome visually. Amplitudes were measured from the EOG records and heights of the excursions were compared between active watching and eyes-closed recall. Sixteen subjects were also asked to perform visual recall and mental arithmetic tasks.

Scoring Visual Imagery Ability

A questionnaire, which referred to imagery only in terms of visual recall or visual imagery, was administered following the recording of eye movements. Afterward the semantics and concepts of visual imagery were discussed with each subject; this provided for voluntary statements and subject-observer

agreement as to word meanings. The questionnaire and voluntary statements were scored with the aid of 2 associates. Scoring was based upon vividness of imagery with respect to detail, color, motion and dimensionality, and on the degree to which visual imagery was employed in thinking and recollection.

Sample Effects

All subjects were asked not to discuss the experiments with others, nonetheless, visual imagery locally became a topic of general conversation. Owing to the propensity of the visualizer to volunteer relevant information, our sample probably reflects the effect of these discussions and thus may not truly represent the general population.

It should also be noted that visual imagery and recall is a subject rarely discussed by either the laiety or professional groups, hence, individual concepts of the subject tend to be foggy.

Results

Eye movements during recall of motion

During active vision, all subjects followed the motion of the metronome in a similar fashion (see Fig. 1A). During recall with eyes closed, eye movements differed widely from individual to individual. Some subjects showed no eye movements at all while others produced remarkably exaggerated movements (see Fig. 1B). Few subjects duplicated the excursions which occurred during active vision. Exaggerated eye movements showed not only right and left swings, but also frequently showed a momentary pause or return to one side, usually to the right. All records showed occasional interposed saccadic movements.

Beat frequency was also not faithfully duplicated during recall, but frequency of eye motion tended to shift gradually between slightly slower and slightly faster rates than the actual metronome beat. Most subjects stated that they were unaware that their eyes moved during recall with the eyes closed.

Scoring of visual imagery ability

Three distinct categories were discerned:

(1) Those subjects who experienced visual imagery, employed it frequently in their thinking, and who readily described their imagery "like the pictures you see in a dream." These subjects almost invariably volunteered information concerning their visual images. They were found to share the following characteristics: (1) their visual images seemed to be outside and in front of the head; (2) they could "see" recalled images, whole or in part, with the eyes open; and (3) with the eyes open, the visual images frequently blocked out the real visual scene. Only those subjects rated as possessing marked visual imagery ("visualizers"—19 of 52) experienced these phenomena. Nine of these subjects consistently reported that their visual images were projected into real visual space and blocked the real visual scene. This was casually confirmed by the experimenter walking in front of the subject who then commented on this visual disturbance. These subjects were not evaluated independently in this study.

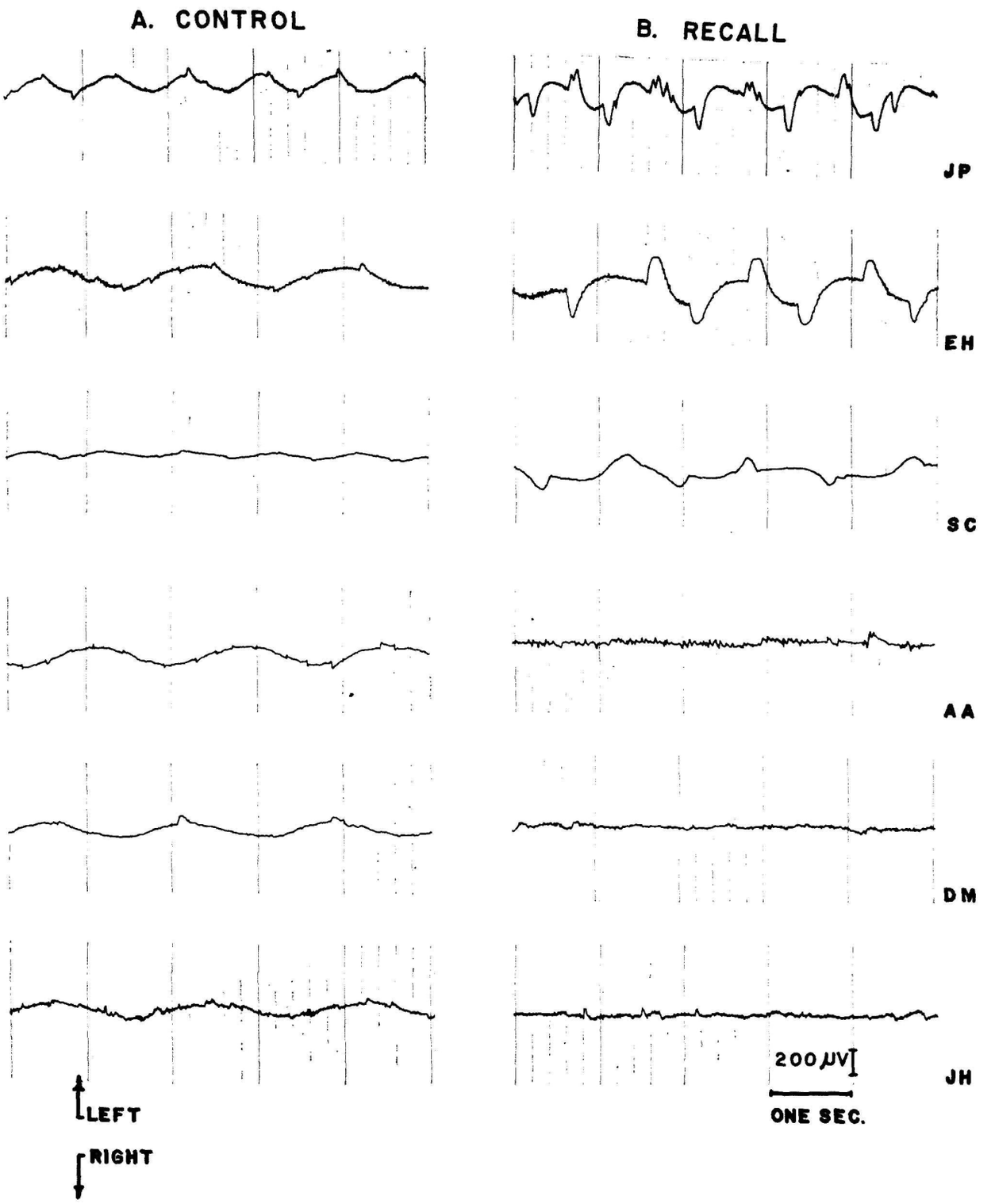

FIG. 1. Examples of recorded eye movements during A., active watching, and B., eyes-closed recall of a beating metronome.

(2) Those subjects who rarely or never experienced visual imagery, never employed it in their thinking, and who described their mental imagery as "a dark gray field" with fragments or echoes of thoughts. These were the "non-visualizers"—15 of 52.

(3) Those subjects who were unclear as to whether mental imagery and visual imagery were similar or different. In these subjects, it was impossible to elicit accurate information concerning either the ability for, or the use of, visual imagery. Such subjects often described the mental image as a picture, but denied

seeing it as a picture. Other subjects reported actually seeing a picture (as in a dream), but that the parts were distorted or hazy.

There were no apparent relationships between these categories and age, sex, or education.

Relation between eye movements and visual recall

The relationship between amplitudes of EOGs during eyes-closed recall of motion (metronome) and ability for visual imagery is shown in Table 1. The incidence of pursuit eye movements in subjects with ability for vivid visual imagery was different from that for subjects completely lacking visual imagery ability at the .02 level. Exceptions occurred in 9 of the 34 subjects compared.

In all instances, following the test, subjects were questioned as to whether they had recalled the motion and how the recall had been accomplished. No clear-cut correlations were found; some subjects who developed eye motion during eyes-closed recall said they were thinking about it but the recall was not visual, while some who reported recalling a vivid visual image of the beating metronome failed to show eye movements. The remainder of test subjects stated that they could "see" the motion in some form (outline, shadow), motion, color or sensation. The latter group was about equally divided between those who exhibited eye movements and those who did not during recall of motion.

Approximately the same proportion of visualizers developed eye movements during visualization and mental arithmetic as did during the metronome test, while parallelly, the majority of non-visualizers did not. See Table 2.

Discussion

In general, studies relating eye movements to visual recall have not been controlled for temporo-spatial aspects of the recall. Deckert's technique permits

TABLE 1

Number of Ss showing change in eye movement amplitude during eyes-closed recall as compared to that during active watching of metronome

Visual Imagery Ability	Increased	Same	Decreased	Total No. Any Movement	No Eye Movement
Vivid (19)	9	3	3	15[a]	4
Intermediate (18)	4	1	5	10	8
None (15)	2	1	2	5	10

[a] $p < .02$ (Fischer exact probability test) for occurrence of eye movements in *Ss* with vivid visual imagery as compared to occurrence in *Ss* with no visual imagery ability.

TABLE 2

Incidence of eye movements in selected subjects during different tasks

Subjects	Number Eye Movements/Number Subjects		
	Attempted Visualization	Mental Arithmetic	Metronome Test
Visualizers	8/10	7/10	8/10
Non-visualizers	2/6	1/6	1/6

concurrent monitoring of a motor component of recall activity and thus permits accurate determination of both time when recall is occurring and with what it is concerned.

The present results revealed that the ocular muscles can be invoked during recall both by subjects who can experience (or report experiencing) visual imagery and by those who do not. The results thus do not tend to support Deckert's suggestion that pursuit eye movements depend upon the development of a cerebral image (Deckert, 1964) since eye movements occurred in subjects who did not report or experience a conscious cerebral image (visual image), and eye movements did not develop in some subjects who did report the presence of a conscious cerebral image. Subjects who reported employing visual imagery to recall the motion either underestimated or overestimated the excursion of the metronome beat. If such subjects are responding to a conscious cerebral image, the inaccuracy of the recall may result from the loss of the reference points seen during active vision. The consistent tendency of eye motion to return to one side suggests a "checking" procedure. In this respect, visual imagery may resemble the auto-kinetic phenomenon of the stationary red dot which moves when seen in a completely dark environment.

The appearance of pursuit eye movements in some subjects who never or rarely experienced (or reported experiencing) visual imagery suggests that associated motor activity may be recalled although the actual stimulus configuration is not visually recalled in conscious form. The absence of eye movements during recall both in some subjects possessing visual imagery ability and in most of those lacking this ability suggests that neither a conscious image nor associated eye movements were recalled and that other modes of recall were being employed.

Whether or not subjects report accurately about experiencing visual imagery, the fact that some report the subjective experience and others do not, itself constitutes a difference among the subjects. The difference may lie in a difference in the conscious awareness of visual images or significance assigned to them. Whatever the underlying mechanism is, it does not appear to relate specifically to development of eye movements on recall of motion.

Although all subjects showed relatively similar eye movements during active vision, such results do not, however, exclude the possibility that visual information may be put into memory quite differently for individuals with visual imagery ability and those who lack the ability. It becomes clear that more intensive comparisons between the processes of active vision and those of visual recall are necessary.

Summary

1. Pursuit eye movements during recall of motion occurred more frequently in subjects who experienced or reported experiencing visual imagery than in those who did not; however, the eye movements were often independent of ongoing visual recall of the motion. The incidence of eye movements during attempted visualization and mental arithmetic in visualizers and non-visualizers was of a similar order as that for recall of motion.

2. Eye movements during recall generally under- or over-estimate both excursion and timing of the original motion.

3. The motor activity involved in watching movement may be recalled in the absence of a conscious visual image of the original movement.

REFERENCES

Aserinsky, E., & Kleitman, N. Two types of ocular motility occurring in sleep. *J. appl. Physiol.*, 1955, *8:* 1–10.

Berger, R. J., Olley, P., & Oswald, I. The EEG, eye movements and dreams of the blind. *Quart. J. exp. Psychol.*, 1962, *14:* 183–186.

Brady, J. P., & Rosner, B. S. Rapid eye movements in hypnotically induced dreams. *J. nerv. ment. Dis.*, 1966, *143:* 28–35.

Deckert, G. H. Pursuit eye movements in the absence of a moving visual stimulus. *Science*, 1964, *143:* 1192–1193.

Dement, W., & Kleitman, N. Cyclic variations in EEG during sleep, and their relations to eye movements, body motility, and dreaming. *EEG clin. Neurophysiol.*, 1957, *9:* 673–690.

Dement., W., & Wolpert, E. A. The relation of eye movements, body motility and external stimuli to dream content. *J. exp. Psychol.*, 1958, *55:* 543–553.

Golla, F., Hutton, E. L., & Walter, W. Grey. The objective study of mental imagery, I. Physiological concomitants. *J. ment. Sci.*, 1943, *89:* 216–222.

Gross, J., Byrne, J., & Fischer, C. Eye movements during emergent stage 1 EEG in subjects with lifelong blindness. *J. nerv. ment. Dis.*, 1965, *141:* 365–370.

Jacobson, E. Electrophysiology of mental activities. *Amer. J. Psychol.*, 1932, *44:* 677–694.

Jeannerod, M., Jouvet, J., & Jouvet, M. Study of ocular movements observed in man in the course of waking and of sleep. *C. R. soc. Biol.*, 1962, *156:* 1407–1410.

Lorens, S. A., Jr., & Darrow, C. W. Eye movements, EEG, GSR, and EKG during mental multiplication. *EEG clin. Neurophysiol.*, 1962, *14:* 739–746.

Slatter, K. H. Alpha rhythms and mental imagery. *EEG clin. Neurophysiol.*, 1960, *12:* 851–859.

Walter W. G., *The Living Brain.* London, 1953.

Walter, R. D. & Yeager, C. L. Visual imagery and electroencephalographic changes. *EEG clin. Neurophysiol.*, 1956, *8:* 193–199.