response will prove to be a valuable tool in the study of problem-solving and other mental processes, which have to date been largely a matter of subjective responses on the part of the subject.

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Pursuit Eye Movements in the Absence of a Moving Visual Stimulus

Abstract. *Subjects instructed to imagine a beating pendulum develop pursuit eye movements of a frequency comparable to the frequency of a previously visualized real pendulum. The appearance of pursuit rather than saccadic movements supports an "outflow" theory for central control of eye movement and suggests an objective technique for the identification of certain types of visual imagery.*

During sleep, dreaming is frequently associated with a specific low-voltage, high-frequency, electroencephalographic pattern accompanied by rapid conjugate eye movements (*1*). These movements may relate to the content of the dream (*2*). Since visual imagery appears in states other than sleep, for example, sensory isolation (*3*), hypnosis (*4*), psychosis, and drug intoxication, specific eye movements might identify and characterize this activity (*5*).

Eye movement responses to visual stimuli can be classified as "saccadic," when there are rapid changes in the fixation point, or as "pursuit," when there are following or tracking movements (*6*). Pursuit movements have been reported to develop only when there is a moving stimulus upon which the eye can fix (*7*). During a study in which we were attempting to correlate induced imagery with various psychophysiologic responses (*8*), pursuit movements were found during imagining conditions in the absence of such a stimulus.

From the large pool of volunteers studied, ten student nurses were chosen who could be hypnotized, and another ten who could not (*9*). All 20 students were given the same tasks of first following (at beat frequency, 0.5 cy/sec) and then imagining a pendulum, and of having dreams and hallucinations about the pendulum. Table 1 shows the sequence of conditions. The eyes of the subjects were 2 meters from the resting pendulum which was released by an electromagnetic device; its position was established by means of photocells at the extremes of the arc. The angle the eyes subtended while following the real pendulum was 36°50″. Electroencephalographic, electrooculographic, and galvanic skin response data were recorded simultaneously on an eight-channel Grass electroencephalograph (*10*). In recording the electrooculogram, the slow time-constant filter was used (electrocardiogram setting, 0.3 sec). Electrodes were placed lateral to each eye (*11*). Subjective verbal reports were recorded and conjoined to the physiologic data by a time-code signal generator.

Eight of the ten subjects who could be hypnotized and all of the subjects who could not be hypnotized developed pursuit eye movements while imagining the beating pendulum in both waking (WCI) and trance (TCI) states. Figure 1 shows a typical record, with the expected development of pursuit eye movements in *A* when the subject is watching the real beating pendulum (WOR). The unexpected appearance of pursuit movements during the eyes-closed-imagining condition (WCI) is shown in *B*; and, for comparison, the development of saccadic movements during the eyes-open-imagining condition (WOS) is shown in *C*. Pursuit movements were characteristic of the eyes-closed-imagining conditions (WCI, TCI), while saccadic movements were characteristic of the eyes-open-imagining conditions (WOS, TOS).

Nonparametric tests were used to analyze the pursuit movement data across conditions. The results of this analysis are summarized in Fig. 2. No significant difference in the number of pursuit movements was found between watching the real pendulum (OR's) and imagining with eyes closed (CI's).

Table 1. Sequence of conditions. All are of 30 seconds' duration except the rest conditions (2 minutes) and TCD condition (1 minute).

Condition*	State	Eyes	Task
RC	Waking	Closed	Rest
RO	Waking	Open	Rest
WOR	Waking	Open	Following
WCI	Waking	Closed	Imagining
WOS	Waking	Open	Imagining
TOR	Trance	Open	Following
TCI	Trance	Closed	Imagining
TOS	Trance	Open	Imagining
TCD	Trance	Closed	Dreaming
TOH	Trance	Open	Hallucinating
TC	Trance	Closed	Resting
TO	Trance	Open	Rest

* After completion of the entire sequence, conditions RC through WOS were then repeated.

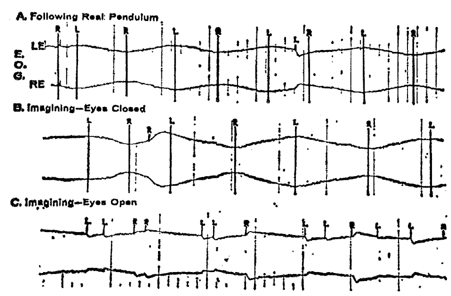

Fig. 1. Electrooculogram obtained during conditions of following and imagining a pendulum (see text). Each record shows the initial 8 seconds of a condition of 30 seconds' duration. (*LE* refers to left eye, *RE* to right eye, *R* to a movement to the right, and *L* to a movement to the left.) The shorter solid line designates a saccadic and the longer a pursuit eye movement.

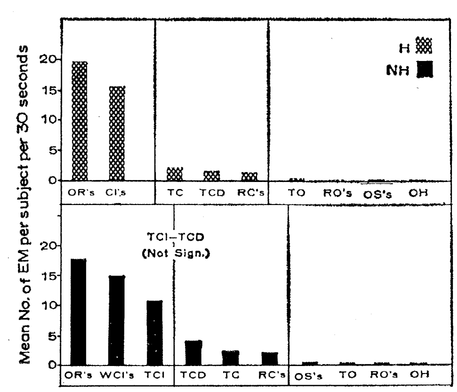

Fig. 2. Significant differences in pursuit eye movements, depending on the conditions. The hypnotizable group is designated *H*, and the group that could not be hypnotized, *NH*. The mean number of *EM* refers to the mean number of pursuit eye movements. For other abbreviations see Table 1. Conditions within a certain block are not significantly different, but conditions across a block are significantly different ($p < .05$; in many instances $p < .01$).

However, the high number of pursuit movements significantly differentiated the eyes-closed-imagining conditions from all the rest, eyes-open-imagining, dreaming, and hallucinating conditions.

In another analysis the number of changes in direction of eye movement was compared (irrespective of pursuit or saccadic designation), and no significant differences were found between the following (OR's), the eyes-closed-imagining (CI's), or the eyes-open-imagining (OS's) conditions. When the frequency beat of the eye was compared to the frequency beat of the pendulum, as expected, a 1 : 1 relationship was found for the conditions of watching the real pendulum (WOR, TOR). In both the eyes-closed-imagining (WCI, TCI) and eyes-open-imagining (WOS, TOS) conditions a 1 : 1 relationship was also approached.

Visual imagery involving a beating pendulum may then be accompanied by pursuit or saccadic eye movements, or both. These findings suggest an objective technique for the identification and differentiation of certain types of visual imagery in the laboratory setting.

In this study, pursuit movements consistently developed in the eyes-closed-imagining conditions in the absence of a real moving visual stimulus. In the past, central control of eye movements has generally been discussed in terms of an "inflow" theory (*6*). Initially, this input was attributed to proprioceptive impulses from eye muscles, but the stretch reflex was soon shown to play little or no role in the eye of man (*6*). Such highly integrated mechanisms as must be involved in pursuit might be attributed to input after the development of a retinal image. These observations, however, suggest that a retinal image in itself is neither the necessary nor sufficient condition for the development of pursuit eye movements. Instead, I suggest that the necessary prerequisite for the elaboration of pursuit eye movements is the development of an appropriate cerebral image. This invokes and supports an "outflow" theory of eye movement control (*6*). This concept also accounts for those findings which relate eye movement to the content of dream imagery or to any imagery developing in the absence of a real visual stimulus.

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11. Alternating-current recordings of eye movements do not provide information for position of the eye relative to the visual field, only information regarding frequency, direction, and change in direction; direct-current recordings, therefore, would possess certain advantages. See C. Kris, in *Medical Physics*, O. Glasser, Ed. (Year Book, Chicago, Ill., 1960), p. 692.
12. This investigation was carried out under the clinical investigator in psychiatry program of the research service of the Veterans Administration. I thank J. Shurley, V. Pishkin, and L. J. West for their suggestions and support, and D. Lagan and R. E. Brooks for technical assistance.

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Luminous Figures: Influence of Point of Fixation on Their Disappearance

Abstract. *When a simple luminous figure is viewed in a darkened room, parts of the figure seem to disappear. Usually, the part that fades from view is the part on which the viewer's gaze is centered (fixated). Figure parts which are not fixated seldom disappear independently; they are lost to view only if the entire figure disappears.*

McKinney (*1*) has recently reported a striking perceptual phenomenon— when luminous figures are observed in a darkened room, fragments of them disappear and then reappear, the cycle continuing indefinitely. In his initial investigation of these disappearance effects, McKinney demonstrated that subjects report many more disappearances when steadily fixating a point on a figure than when moving their eyes around the boundaries of the figure or when moving their eyes back and forth between a central figure and a peripheral figure.

Although McKinney did establish the significance of fixation as a determinant of the frequency of disappearance, he did not directly investigate the relationship between the particular parts of a figure that are fixated and the subsequent parts which disappear. He compared only the frequencies of disappearance under conditions of fixation and nonfixation.

It is important to study the relationship between loci of fixation and the loci which disappear, because it is the fixation point that may be the primary factor in determining which parts of the figure will be seen to disappear. McKinney has asserted that "disappearance occurred in perceptual units, not at random" and "meaningful perceptual units remained. . ." (*1*, p. 404). There is a critical question, however, as to whether the meaningfulness of the perceived disappearances was inherent in the perceptual process itself or in the scanning and fixating that preceded the perception of disappearances. Since McKinney did not manipulate loci of fixation, it is quite possible that the meaningfulness of the disappearances reported by his subjects was a secondary effect, produced indirectly by the meaningful manner in which his subjects fixated upon the parts of the test figures.

The data in this report indicate that the part of a figure upon which a subject is centering his gaze (fixating) is the part which is most likely to disappear.

These data were collected by tape recording the observations of subjects as they viewed luminous figures in a darkened room. The 2.5-cm lines of the figures (Fig. 1, *A–C*) were painted (*2*) on sheets of violet construction paper measuring 25 × 30 cm. The subjects, who were not previously adapted to the dark, viewed binocularly the individually presented figures while seated 2.7 m from a black display board. The figures used were smaller