In a previous article (*4*) some studies were described which were conducted at the sensory deprivation laboratory at Princeton University with the goal of identifying hallucinogenic factors in sensory deprivation. The article concluded with the suggestion that some form of visual stimulation may be necessary for the production of hallucinations. In that series of experiments, as in the series reported here, a very specific set of criteria was used before a "reported visual sensation" was classified as a visual hallucination. These criteria were (i) uncontrollability of onset, content, and termination; (ii) "out-thereness"; (iii) scannability; and (iv) apparent reality.

A summary of the experimental procedures and of the results obtained is presented in Table 1. Studies 1 to 6 were described in the previous article (*4*); in studies 7 to 12 we attempted to specify the hallucinogenic factor in study 2, the only one of the earlier series in which such a factor seemed to be operating. As the table shows, none of these manipulations succeeded in eliciting visual hallucinations from any considerable proportion of the subjects.

For study 7, we used visual stimuli which were small and varied (presumably, more like those used in study 2 than the nonhallucinogenic stimulus of study 6). In study 8 we presented stimuli which were not only small and diverse, but in addition were unstructured and varied in location (*5*). In studies 9, 10, and 11 we tested other hypotheses about hallucinogenic influences in sensory deprivation. In study 9, motility was greatly reduced (see *6*); in study 10, subjects were made highly anxious concerning the sensory deprivation experience by being given fear-arousing instructions (see *3*); and in study 11, previous experience with unusual visual imagery [with a "Ganzfeld" (*7*)] and instructions strongly encouraging the subject to expect and to report such imagery (see *1*, pp. 17–21) were coupled with the visual stimulation administered in study 8. Finally, study 12 was a replication [except for the duration of confinement, which is apparently not a crucial factor (*1*)] of study 2; in the replication, but not in the original study, no hallucinations were reported.

If, following the procedures of other experimenters, we had classified *any* "reported visual sensation" as an hallucination, then our results would have appeared to be quite similar to those which have been reported previously, for the majority of subjects in those studies where we collected "reported visual sensation" data did experience such sensations (see Table 1). For this reason, we strongly urge that, before discussing the phenomenon of hallucinatory imagery in sensory deprivation, experimenters adopt some standard set of criteria and classify "reported visual sensations" as meeting or not meeting these criteria. This would be no guarantee against disagreements; but it would at least ensure that we are all disagreeing about the same thing.

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References and Notes

1. M. Zuckerman and N. Cohen, *Psychol. Bull.*, in press.
2. T. I. Myers, paper read at the 1961 meeting of the Am. Psychol. Assoc.
3. J. P. Zubek, *Brit. Med. Bull.* **20**, 38 (1964).
4. J. Vernon, T. Marton, E. Peterson, *Science* **133**, 1808 (1961).
5. Plates I, IV, VI, and VII of the "Rorschach test" [H. Rorschach, *Psychodiagnostics Text* and *Psychodiagnostics Plates* (Huber, Bern, 1948)].
6. S. J. Freedman, H. U. Grunebaum, M. Greenblatt, in *Sensory Deprivation*, P. Solomon *et al.*, Eds. (Harvard Univ. Press, Cambridge, Mass., 1961), p. 58.
7. The homogeneously illuminated goggles of study 4 were used to produce a "Ganzfeld effect" [see W. Metzer, *Psychol. Forsch.* **13**, 6 (1930)].
8. Financial support for this research was received from the Office of the Surgeon General, U.S. Army (DA 49-007-MD-671) and the NSF (G-21762). The help of the following research assistants is gratefully acknowledged: R. J. Grissom, T. Marton, E. Peterson, R. Legrand, and W. P. Rust.

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Primate Retinal Responses: Slow Changes during Repetitive Stimulation with Light

Abstract. *Sudden, repetitive illumination of the dark-adapted monkey eye produces transient changes in the electroretinogram and transocular potential which can last an hour or longer.*

During studies of steady-state retinal responses of monkeys (*Macaca mulatta*) to flickering monochromatic stimuli of large angular subtense, an extremely slow oscillation in the electroretinogram has been observed which does not appear to have been completely noticed by earlier investigators. The phenomenon is of importance because it complicates quantitative evaluation of the electroretinogram especially after stimulation with moderately bright light. It is of additional interest in demonstrating the exremely long time that must elapse for some retina responses to reach a steady-state after sudden changes in illumination.

The monkeys studied in these ex-

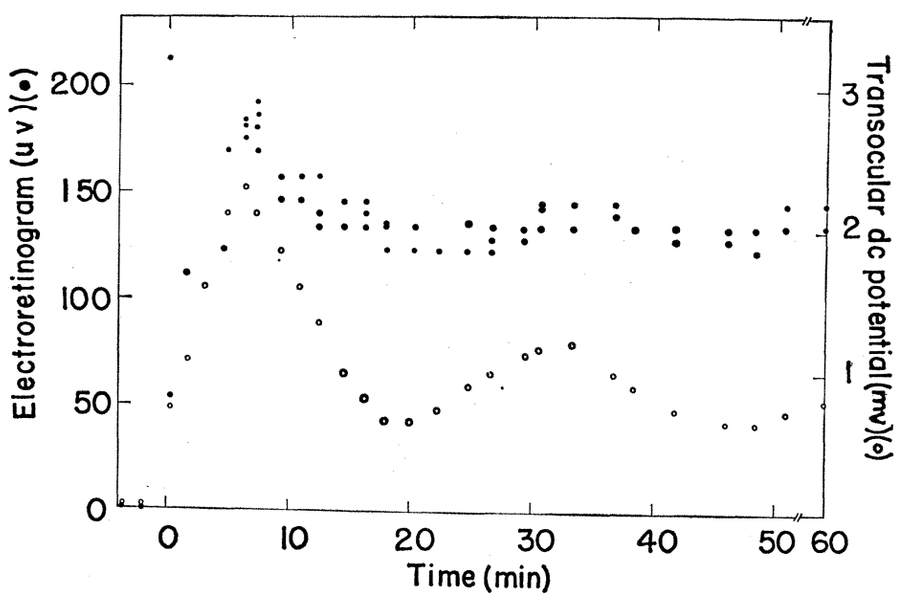

Fig. 1. Changes in the electroretinogram and transocular d-c potential during stimulation with square-wave monochromatic (610 mμ) light at 4 cy/sec. The flickering stimulus has equal intervals of light and dark, and begins at time zero. The electroretinogram scale represents peak amplitude of responses photographed from an oscilloscope.

periments were anesthetized with Nembutal, maintained firmly in place by means of a mouthpiece, and stimulated with a Maxwellian field subtending 90 degrees of visual angle through a pupil dilated by either phenylephrine hydrochloride or cyclopentolate hydrochloride or both. A direct-current (d-c) amplification system with silver chloride electrodes recorded both the electroretinogram and the transocular d-c potential simultaneously. One electrode was placed within Tenon's capsule, behind the globe, and the other in a corneal contact lens. The light source was a well regulated 1000-watt high-pressure Xenon arc lamp, the output of which was continuously monitored during the experiments. The monkeys were routinely dark-adapted for 20 minutes before flickering stimuli were presented to the eye. Stimulation was continued until the retinal responses reached a steady-state, the criterion being the production of a constant electroretinogram after each stimulus of the flicker.

With flickering lights which did not raise the retinal illumination greatly from the dark-adapted state, the electroretinogram came to an equilibrium with the stimulus within seconds and there was little or no detectable shift in the transocular potential. If the intensity of stimulation was greater, transient changes in the electroretinogram became prolonged and the transocular potential exhibited a slow transient increase. With moderately bright illumination, the amplitude and waveform of the electroretinogram changed considerably during the first few minutes of stimulation; thereafter the amplitude slowly increased to a maximum at 5 to 10 minutes and then decreased again to a minimum at 20 to 25 minutes. This slow oscillation of the amplitude of the electroretinogram gradually decreased in a lightly damped manner after an hour or more of maintained stimulation. The transocular potential showed a similar oscillation which appeared to be in phase with that of the electroretinogram (Fig. 1). The phenomenon occurred with either sinusoidal or square-wave light functions and with energy from both ends of the visible spectrum. The energies necessary to elicit these changes were not excessively large, being in the order of 10^{13} quanta sec^{-1} deg^{-2} at 502 mμ.

Similar light-induced oscillations in the transocular d-c potential of the human eye have been described (*1*) and this study demonstrates their counterpart in the monkey. Parallel oscillations in the electroretinogram have not been reported hitherto. Biersdorf and Armington (*2*) observed that the human electroretinogram can slowly increase during light adaptation and speculated upon the possible relationship between this and a similar change in the d-c potential of the human eye. This evidence from the monkey eye strongly supports their conjecture and makes it appear likely that the oscillatory changes in the electroretinogram also occur in man.

Methods other than light stimulation which can alter the transocular d-c potential such as either electric current (*3*) or the administration of sodium azide (*4*) also influence the amplitude of the electroretinogram. These effects are relatively rapid. The slow, oscillatory behavior observed in these retinal responses appears to be a unique consequence of light stimulation.

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References and Notes

1. C. Kris, *Nature* **182**, 1027 (1958); H. Kolder, *Arch. Ges. Physiol.* **268**, 258 (1959).
2. W. R. Biersdorf and J. C. Armington, *J. Opt. Soc. Am.* **50**, 78 (1960).
3. R. Granit and T. Helme, *J. Neurophysiol.* **2**, 556 (1939).
4. W. K. Noell, U.S. Air Force School of Aviation Medicine, Project No. 21-1201-0004, Rept. No. 1 (1953).
5. We thank K. Link for her assistance in this project.

2 June 1964

Vestibular Nuclei: Activity of Single Neurons during Natural Sleep and Wakefulness

Abstract. *The rate of spontaneous discharge of second-order vestibular neurons is higher during wakefulness than during drowsiness and synchronized sleep. The activity of units recorded from the lateral (and superior) vestibular nucleus remains unmodified or is slightly increased during desynchronized sleep, in spite of the complete disappearance of the postural tonus. Units in medial and descending vestibular nuclei show bursts of rapid discharge associated with the eye movements characteristic of desynchronized sleep.*

Sleep characterized by the well-known electroencephalographic patterns of slow waves and spindles (synchronized sleep) is interrupted by short episodes of low-voltage, fast waves (desynchronized sleep) (*1*, *2*). The desynchronized sleep, at least in the cat, appears to be deeper than the synchronized phase (*3*).

During episodes of desynchronized sleep, the electromyogram of the cervical antigravity muscles is silent (*2*), while rapid eye movements suddenly appear (*1*). Neurons localized

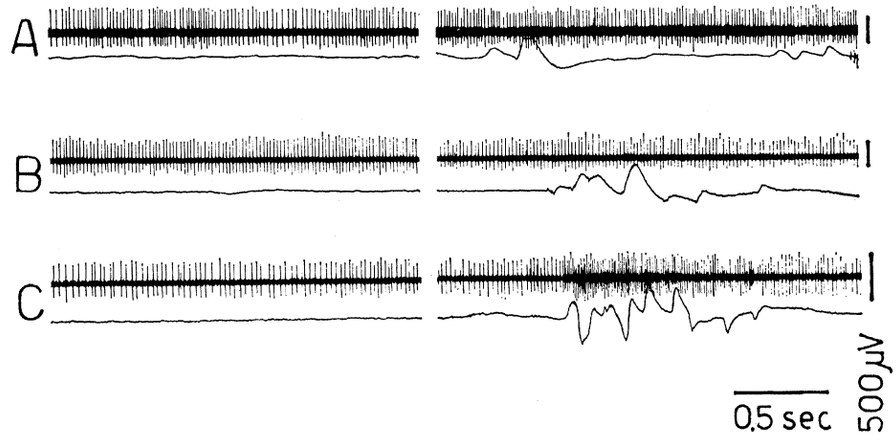

Fig. 1. Spontaneous discharge of single units recorded in different experiments from lateral (*A*), superior (*B*), and medial (*C*) vestibular nucleus during synchronized sleep (left column) and during the episodes of rapid eye movements occurring in desynchronized sleep (right column). Upper records show the unit activity; lower records show the eye movements recorded from electrodes placed above the orbit. Voltage calibrations correspond to 500 μv and apply to the units. Time calibration: 0.5 sec.