respect to the reinforcement rate cycle) (*5*). The overall response rates for the three birds, 116, 119, and 437, also showed good agreement at 33.6, 33.6, and 39.4 responses per minute, respectively.

While it might be expected that both phase lag and amplitude of oscillation will be functions of variables such as cycle length, length of training, and so on, later experiments suggest that the lag, at least, is little affected by a change in cycle length from 30 to 60 minutes. Skinner's experiment (*4*), which can be considered as a 10-minute cycle, also shows a phase lag close to 180 degrees. The general pattern of responding shown in Fig. 2 emerged quite early in training, and later sessions served mainly to reduce day-to-day variation; the phase lag was always close to 150 degrees, with the birds tending to peck most rapidly when reinforcements came least frequently. The similar phase lag shown by the third and fourth cycles in Fig. 2, together with the results of later experiments, suggest that lag is likewise not a function of the number of cycles per session. Given that the cyclic pattern is established, therefore, it seems always to show a lag near 180 degrees.

Figure 3 depicts the relation between response rate and reinforcement rate implicit in the results shown in Fig. 2. These points were derived by displacing for each animal the response rate functions along the abscissa until they were in phase with the reinforcement function, and then plotting corresponding values as shown (*5*). There is reasonable agreement among the three animals on the form of the function, and the line drawn in Fig. 3 (which represents the mean of both ascending and descending parts of the function for all three birds) is quite representative. The relation is clearly not a linear one, although these data do not afford a decision between concave-upward and sigmoid alternatives.

The procedure described here has two essentially independent properties: (i) the cyclic change in reinforcement density over time, and (ii) the identity of the temporal pattern of reinforcements in successive sessions. The second property may, in the long run, prove to be the more useful as a tool, since it permits reliable estimation of an organism's adjustment to any desired sequence of interreinforcement intervals. The results of this particular experiment, which follow from the cyclic property of the procedure, suggest links with established analytical methods of systems engineering (*6*) and emphasize once more the usefulness of response rate as a dependent variable in the analysis of behavior (*7*).

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References and Notes

1. The programming tape can only specify the *minimum* interreinforcement interval; the *actual* interval is determined by the organism since reinforcement is always conditional upon a response. In practice the minimum value is closely approached because response rates are ordinarily high by comparison with the interreinforcement interval.
2. C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (Appleton-Century-Crofts, New York, 1957).
3. All timing equipment was halted during the three-second reinforcement cycle.
4. The only other example I have discovered of the kind of cyclicity discussed here (apart from fixed-interval responding) is mentioned by B. F. Skinner in *The Behavior of Organisms* (Appleton Century, New York, 1938), p. 272; this example shows no "scalloping" despite the use of only two interreinforcement intervals.
5. These values were computed for the penultimate cycle, between the 12th and 18th 5-minute periods.
6. In particular the methods of sinusoidal frequency analysis, see J-C. Gille, M. J. Pélegrin, P. Decaulne, *Feedback Control Systems* (McGraw-Hill, New York, 1959), for modern techniques; H. von Foerster, in *Homeostatic Mechanisms* (Brookhaven Symposia in Biology No. 10, 1957), gives a short introduction to control theory for biologists.
7. The significance both of response and reinforcement rates is widely documented; see B. F. Skinner, *Am. Psychol.* **18**, 503 (1963); R. J. Herrnstein, *J. Exptl. Anal. Behavior* **7**, 27 (1964); D. Premack, *Psychol. Rev.* **66**, 219 (1959).
8. Supported by grants from NSF to Harvard University. I thank Dr. R. Herrnstein for advice and criticism. Thanks are also due to Mrs. Antoinette Papp and W. Brown, Jr., for assistance.

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Visual Hallucinations during Sensory Deprivation: A Problem of Criteria

Abstract. *Attempts to elicit visual hallucinations in sensory deprivation indicate the desirability of adopting a set of criteria for identifying hallucinations as distinct from reported visual sensations in general.*

Although the frequent occurrence of visual hallucinations was one of the most dramatic reports of early workers in sensory deprivation, later experimenters have obtained less consistent results. In a recent review (*1*), Zuckerman and Cohen indicated the tremendous variety of procedures and results in this area, and attempted to identify the factors which lead to the appearance of visual imagery in sensory deprivation. Because of the lack of standardized terminology among experimental reports, the review passes lightly over what we consider to be an important problem. This is the question of differentiating between hallucinations and "reported visual sensations" (*2*) in general. As has been pointed out, the question of criteria must be answered before results can be adequately evaluated: hypnagogic imagery, daydreams, fantasies, and other sensations can be extremely vivid in sensory deprivation, and "If . . . criteria [for hallucinations] could be applied to the earlier studies, fewer hallucinations would probably be noted" (*3*, p. 39).

Table 1. Summary of the hallucination studies conducted at Princeton University.

Experimental conditions						No. of subjects reporting:	
No. of study	Duration (hr)	Visual stimulation	Motility	Other	No. of subjects	Visual hallucinations	Visual sensations
1	48	Red lamp*	Extensive		4	0	
2	72	Light leaks*	Extensive		9	6	
3	96	None	Moderate		9	1	
4	48	Diffuse†	Moderate		10	2	
5	48	Diffuse†	Moderate	Thermal noise†	11	0	
6	48	Amorphous*	Moderate		10	1	7
7	48	Geometrical figures*	Moderate		5	1?	4
8	48	Rorschach*	Moderate		5	1?	3
9	24	None	Restricted		7	0	
10	24	None	Restricted	Anxiety arousal	8	1	
11	24	Rorschach*	Restricted	‡	7	0	7
12	48	Light leaks*	Extensive		4	0	2

* Intermittent. † Constant. ‡ Experience with, expectation of, and encouragement to report unusual visual sensations.

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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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-

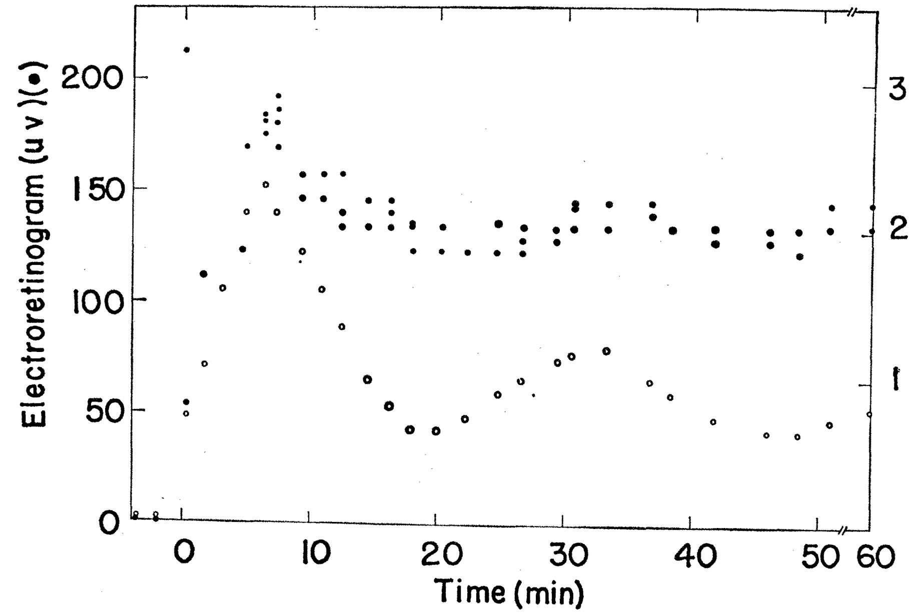

Fig. 1. Changes in the electroretinogram and transocular d-c potential during stimulation with square-wave monochromatic (610 mμ) light at 4 cy/sec. The flickering stimulus has equal intervals of light and dark, and begins at time zero. The electroretinogram scale represents peak amplitude of responses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