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Changes in critical flicker frequency during prolonged visual deprivation

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Subjects were tested on the critical flicker frequency during a 1-week period of visual deprivation (either homogeneous illumination or darkness). Deprived subjects showed no significant differences from a confined control group. Results were discussed in relation to previous research, Schultz's theory of "sensoristasis" and Sharpless' revision of the "law of denervation."

Schultz (1965), in his theory of sensoristasis, suggests that an organism's sensitivity to stimuli is partly a function of the variability in the overall sensory environment. The organism, he maintains, strives to keep balance between input variability and sensitivity to that input. It is argued that when variability is very low (as in sensory deprivation), a sensitizing of the cortical receiving areas occurs by means of the ascending reticular activating system (ARAS). The result of a reduction in normal stimulus variation is predicted to be a general raising of sensitivity to whatever stimuli remain (Schultz, 1965, prediction 4, p. 32).

Several studies conducted at the University of Manitoba have supported Schultz's prediction. A 1-week period of visual deprivation was shown to improve performance in various threshold tasks involving the nondeprived modalities. Thus, performance on tests of heat and pain sensitivity, tactile temporal fusion (Zubek, Flye, & Aftanas, 1964; Zubek, Flye, & Willows, 1964), auditory flutter fusion (Duda & Zubek, 1965; Pangman & Zubek, 1972), and olfactory and gustatory detection (Schutte & Zubek, 1967) improved following visual deprivation. Although there were a few measures which did not show improvement (e.g., gustatory sensitivity to hydrochloric acid and quinine; Schutte & Zubek, 1967), results of this series of experiments show the sensoristatic theory to be a useful predictor of cross-modal deprivation effects.

Two lines of indirect evidence, however, do not seem to support the idea that sensoristasis is the rule within the deprived modality itself. Durations of up to 14 days of perceptual deprivation (homogeneous illumination and white noise) have failed to improve the CFF or brightness discrimination (Zubek, 1969, pp. 212-214). Similarly, periods of up to 14 days of monocular deprivation produced no alteration in the CFF of the occluded eye (Bross & Zubek, 1972; Zubek & Bross, 1973a, b).

Only two studies bear directly on the question of the sensitivity of the deprived modality during full visual deprivation, and these studies have yielded apparently contradictory results. Gibby, Gibby, and Townsend (1970) found that visual deprivation of just 3 h (darkness or homogeneous illumination) produced an enhancement of subjects' performance on the CFF. On the other hand, Duda (1965) found no changes in the CFF following 1 week of darkness. One possible explanation of the different results is the different deprivation periods employed. It is possible that an enhancement in the CFF occurs early in the deprivation period, as found by Gibby et al., but dissipates until, after 1 week, no change is evident as reported by Duda. The purpose of this study was to resolve the apparent discrepancy in results of the two previous studies by determining the CFF frequently during a 1-week period of visual deprivation.

METHOD

Subjects

The subjects were 36 university students who volunteered to wear a blindfold over both eyes for a period of 1 week. They were subdivided into two experimental and one confinement control group, each containing 12 subjects. All of the volunteers were paid for their participation in the experiment.

Deprivation Procedure

The subjects were required to live, in groups of two, for 7 days, in a furnished windowless room (3.45 × 2.77 m) which contained a small sofa, chairs, two sleeping mattresses, a radio, and brightly colored pictures on the walls. They were free to move about their living quarters and were encouraged to converse with each other and to listen to the radio in the daytime and evening. They were provided with meals in their room and were allowed approximately 8 h of sleep each night.

During the entire period, the subjects in one of the experimental groups wore a black opaque mask over both eyes while the subjects in the other wore a white translucent mask which produced a Ganzfeld-like condition of diffuse, unpatterned vision. The average illumination under white mask, at sitting height, was

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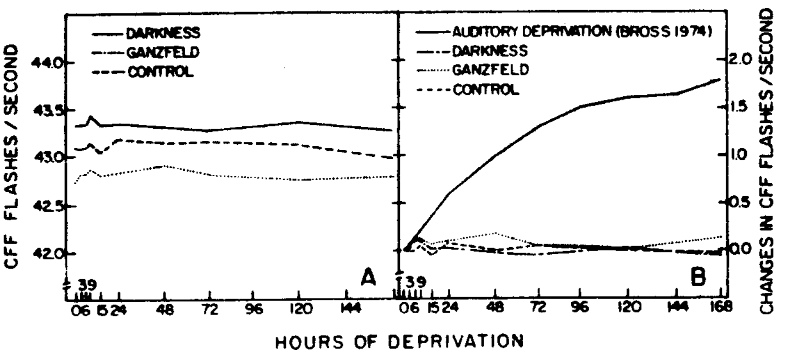

Figure 1. (A) Temporal changes in the CFF of visually deprived subjects (homogeneous illumination or darkness) and of confined control subjects. (B) Temporal changes in the CFF of the present study and that of Bross (1974).

approximately 215.38 lux. Periodic checks were made to ensure that there were no light leaks. The vision of the confinement control group was not restricted. However, to provide a living condition somewhat similar to that of the two experimental groups, they were not permitted to read.

All subjects were required to report to the laboratory on the evening before the confinement period began. This preconfinement procedure not only acquainted the subjects with the personnel, regulations, nature of the living quarters, and the test procedure itself, but also ensured that all the subjects received approximately the same amount of sleep prior to the start of the experiment on the following morning.

Apparatus and Test Procedure

The monocular CFF of each subject was determined at intervals of 0, 3, 6, 9, 15, 24, 48, 72, 120, and 168 h. Each of the 10 test sessions was preceded by 20 min of binocular dark adaptation (the duration employed by Gibby et al., 1970) and a meal or a snack accompanied by a sweet chocolate bar (to control for possible effects of changes in blood sugar level on the CFF). Since the subjects wearing the black mask were in constant darkness for the entire 7-day duration, the dark-adaptation procedure was necessary only at the beginning of the experiment (0 h). The experiment began in the morning, with the measurements being taken between 9:00 a.m. and 10:15 a.m. The subjects were tested in a constant order, with each subject's testing time not varying by more than 5 min on the successive occasions. The measurements were taken in a room adjacent to the living quarters.

The stimulus consisted of a white light which was presented monocularly by a cold cathode modulating lamp (Sylvania, Type R1131c; crater diameter = 0.236 mm) mounted at the rear of a standard viewing chamber (Lafayette, Model 1202c). The subject was required to centrally fixate the stimulus as it was presented through a 1.25-cm-diam Plexiglas diffuser. The stimulus-to-eye distance was 36.25 cm and the visual angle subtended was 2°10′, a value assuring full foveal stimulation. The inside of the chamber was lined with dull black material to eliminate reflectance. The front of the chamber was constructed of molded rubber which fit closely to the subject's face in order to eliminate extraneous light. The flicker-generating apparatus (Grason-Stadler, Model E622) was set at a light-dark ratio of 0.50 and a lamp luminance during the "on" phase of approximately 35 cd/m^2. Eight trials, each separated by a 5-sec intertrial interval, were presented to the preferred eye of one-half of the subjects and to the nonpreferred, or weaker, eye of the other half. The descending method of limits was used with initial stimulus presentation above fusion. The subject's task was to report the first indication of a flickering sensation. The arithmetic mean of these eight trials was taken as the descending CFF threshold for each subject.

Visual preference[1] was determined by a special viewing device—the R. O. Gulden 17. A similar proportion of subjects preferred the right eye and left eye in each group, and therefore, the results from the two eyes were pooled for purposes of statistical analysis.

RESULTS

Figure 1A summarizes the results obtained from the two experimental and one confined control groups. It can be seen that the CFF of the three groups of subjects is similar at all 10 test periods. An analysis of variance (mixed design for repeated measures, Myers, 1966) confirmed the fact that there were no significant between-group effects, between-duration effects, or interaction effects.

The absence of an effect in the present study is shown strikingly in Figure 1B, in which a significant enhancement of the CFF after prolonged auditory deprivation is illustrated (Bross, 1974). The enhancement of about 2 cps is typical of the many studies at the University of Manitoba which have investigated the effects of various types of sensory deprivation on the CFF.

DISCUSSION

The failure in this study to find significant alterations in the CFF during 1 week of either darkness or homogeneous illumination is in agreement with the earlier findings of Duda (1965) but not with those of Gibby et al. (1970). A careful look at the methodology of Gibby et al. (Gibby, 1966) provides a clue as to the reason for this puzzling discrepancy. The three groups employed by Gibby et al.—control, darkness, and homogeneous illumination—were tested in two sessions 1 week apart. The initial session was identical for each group. Twenty minutes of dark adaptation was followed by the CFF test; padded earphones were then put on the subjects and several auditory tests were administered. This procedure was repeated 1 week later for the control group. The experimental groups, however, underwent a 3-h period of visual deprivation *during which the padded earphones were worn*. It is probable that the earphones, together with the experimenter's failure to provide auditory stimulation (Gibby, 1966, p. 25), inadvertently created a condition of relative auditory deprivation *in addition* to the planned visual deprivation. It is further suggested that the inadvertent silence rather than the visual deprivation accounts for the findings of Gibby et al. Recent evidence from the University of Manitoba indicates that auditory deprivation does lead to improvements in the CFF (Bross, 1974).

It is interesting to note that the present results would not have been predicted from research involving visual deprivation in animals. This research tends to show detriments in both electrophysiological and psychophysical measures (e.g., Riesen, 1961; Wiesel & Hubel, 1963). Most animal research, however, has assessed the effect of deprivation on maturational processes (by employing dark-reared subjects). One exception is the work of Cornwell and Sharpless (1968), who found a detriment of the b wave in the ERG of mature kittens undergoing relatively short-term deprivation. However, the detriment found by these investigators is difficult to relate to the present results, since the locus of fusion of intermittent stimulation is almost certainly not retinal (see Brown, 1965). What seems to be required in order to relate the animal and human research in this area is a systematic monitoring of responses to the test stimuli at the various levels of the deprived system.

The weight of evidence, then, indicates that the CFF is not altered by visual deprivation of up to 1 week's duration. Such a finding clearly has implications for Schultz's theory of sensoristasis. The ARAS, which presumably mediates the sensoristatic process, is a general cortical arousal system (Lindsley, 1961), which should, therefore, lead to increased sensitivity in the deprived as well as the nondeprived modalities. Findings such as those presented here constitute a major exception to the support for Schultz's prediction and raise the possibility that the theory is too general to account for both within- and between-modality deprivation results.

It might be more useful to consider some deprivation effects as being mediated by a mechanism other than the ARAS. Bross and Zubek (1972) suggested that monocular deprivation might be a functional analogue of surgical deafferentation [Cannon and Rosenblueth's (1949) law of denervation]. It was contended that the occluded eye in a monocular deprivation experiment is *functionally* denervated and that this denervation—like surgical denervation—leads to a state of supersensitivity in *related* structures. The occluded eye itself, however, being the analogue of the surgically destroyed tissue, is not affected by its own disuse. Such a view is compatible with Sharpless' (1964) revision of the law of denervation to include "disuse of neural pathways." An explanation of the present results may be subsumed under the same logic. The visual system is rendered nonfunctional in binocular deprivation, and as such it may lead to supersensitivity in other modalities (through the reticular systems, perhaps) while remaining unaltered itself.

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NOTE

1. Eye preference was determined by having the subject read a line on a Snellen chart while looking through a small hand-held device (Gulden R. 17) which permitted only monocular viewing. The eye chosen by the subject on two successive trials was designated "preferred."

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