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CHANGES IN CRITICAL FLICKER FREQUENCY DURING ONE WEEK OF BINOCULAR DEPRIVATION

by

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ABSTRACT

A series of studies conducted at the University of Manitoba has demonstrated that a prolonged period of monocular deprivation of up to 14 days duration produces an unusual temporal pattern of visual performance in the nonoccluded eye, viz., an initial decrease in the critical flicker frequency (CFF) followed by an increase of a negatively accelerating nature. Furthermore, this "depression-enhancement" or D-E phenomenon was only obtained when the one eye was in darkness but not when it was exposed to diffuse homogeneous illumination (Ganzfeld). The purpose of this thesis was to test a theoretical prediction that the D-E phenomenon probably would not occur during a condition of binocular deprivation.

Three groups of male university students, each containing 12 subjects, were required to live in a windowless room for a duration of one week. One group of subjects served as confinement controls while the other two were exposed, binocularly, either to constant darkness or diffuse homogeneous illumination (Ganzfeld). Measurements of the CFF were taken before and then after 3, 6, 9, 15, 24, 48, 72, 120, and 168 hours of confinement. An analysis of variance revealed no significant differences in the CFF of the three groups of subjects at any test period, thus providing experimental support for the theoretical prediction.

The results of this experiment, together with those obtained from the earlier monocular deprivation studies, were related to the denervation supersensitivity phenomena which are known to occur after partial surgical deafferentation of the lower primary sensory system.

CHAPTER I

THE PROBLEM AND INTRODUCTION

Statement of the Problem

One important topic in the area of sensation and perception about which very little is known is the nature of visual performance during prolonged periods of monocular deprivation. In an attempt to throw some light on this problem, a series of studies has been conducted at the University of Manitoba in which the critical flicker frequency (CFF), a measure of temporal visual acuity, was determined in adult subjects at periodic intervals during 1 to 14 days of monocular deprivation. The results of these studies indicated no significant changes in the CFF of the visually deprived eye at any test duration. However, the temporal performance of the nonoccluded eye was characterized by an initial decrease in the CFF (i.e., poorer acuity) at 3 and 6 hours, a reversal to the pre-experimental baseline at 9 hours, and then a negatively accelerating increase in the CFF as a function of deprivation duration. Furthermore, this "depression-enhancement" or D-E phenomenon was only obtained if a black rather than a translucent eye patch was employed, a finding which indicates that it was produced by an absence of visual stimulation *per se* and not by an absence of pattern vision.

As an explanation of this unusual monocular phenomenon, it has been suggested that it might be placed in the same general category as some of the denervation supersensitivity effects which are known to occur in the higher neural centers after *partial* surgical deafferentation of the lower primary sensory systems. (These denervation effects, it is important to note, are frequently preceded by a period of decreased sensitivity.) If one accepts this hypothesis, then it would follow that the D-E phenomenon should not occur during a condition of total visual deprivation. This prediction will be tested in a study in which the CFF will be determined at periodic intervals during one week of binocular deprivation.

Introduction

One important topic which has long intrigued both scientists and the general public is the behavioral and physiological status of an individual who is required to live in an environment in which the level and variability of visual, auditory, and tactual-kinesthetic stimulation is reduced. What happens to him during this condition when his brain is exposed to a minimum of sensory stimulation? The laboratory attempts to achieve such a condition, and also appraise its effects, are commonly referred to by such terms as sensory isolation, sensory deprivation, and perceptual deprivation.

Although interest in sensory deprivation and isolation has had a long history e.g., both as a punitive and a therapeutic device over the centuries, the first experimental study of its possible effects only began in 1951--at McGill University (Bexton, Heron, & Scott, 1954). The results were quite startling and unexpected. The subjects, who were placed in an isolation chamber for several days under a condition in which their hearing, vision, and motor activity was restricted, showed a variety of unusual phenomena e.g., complex and vivid hallucinations, delusions, increased susceptibility to persuasion, impaired cognitive and perceptual performance, and a slowing of the occipital alpha waves. These dramatic results, together with several post-World War II developments, such as the arrival of the space age in October 1957 and research on the reticular activating system (an "arousal" system whose action is dependent upon variable sensory stimulation), generated world-wide interest in the effects of sensory isolation resulting, at present, in several books and approximately 1,000 articles (see Zubek, 1969 for review). Although most of this research has been conducted in North America, studies similar to those at McGill have also been done in Japan, England, the Netherlands, Germany, Italy and Czechoslovakia.

A survey of this voluminous literature of the past 20 years indicates that research on sensory deprivation has passed through four stages of development. The first stage was characterized by numerous and largely exploratory studies whose purpose was to determine the breadth of the sensory deprivation effects. In these studies a wide range of affective, cognitive, sensory, perceptual-motor, and physiological and biochemical measures were employed. This research, though it confirmed most of the McGill findings and extended the range of the phenomena, indicated that the observed effects were much more complex in nature than was first believed. For example, contrary to expectations, numerous instances of both <u>improvements</u> as well as impairments in cognitive and sensory performance were reported, the specific effects being largely dependent upon the particular measures employed. In the second stage, the orientation of the research was towards greater methodological rigor emphasizing the use of control baselines and more refined measurement techniques. This work served the useful purpose of checking on the validity of the earlier results.

Since these two early stages produced findings, many of which seemed to defy any satisfactory theoretical explanations, attempts were next made to clarify their nature by the performance of parametric studies. In this third stage, an appraisal was made of the specific role of the numerous variables involved in the complex sensory deprivation situation e.g., social isolation, confinement, recumbency, the subject's experimental set or expectancy, duration of isolation, and the individual contribution of the various deprived sense modalities. This research clearly indicated that many of the classic phenomena could be produced by physical confinement or sensory restriction, either alone or in combination. Social isolation _per se_ was relatively unimportant. Furthermore, it was demonstrated that duration of isolation may be a critical variable e.g., performance on a particular task might be either impaired or improved depending upon when the measurements were taken.

The final or current stage is characterized by a change in orientation away from viewing sensory deprivation as an _area_ of investigation to a realization that it is a very versatile and useful _tool_ or technique which can be used by many kinds of specialists for investigating particular problems or topics. This "new look" can best be illustrated by reference to two major projects which are currently being conducted at the University of Manitoba. The first of these pertains to the investigation of intersensory effects, a topic with a long history of inconclusive and contradictory findings (Ryan, 1940; London, 1954). In this research, subjects who were exposed to visual deprivation alone for a duration of one week showed a significant increase in cutaneous, auditory, olfactory, and gustatory sensitivity, effects which persisted for several days after the restoration of normal vision (see Zubek, 1969a for review). This research, indicating that understimulation in one modality may be compensated for in another modality, is of considerable theoretical importance since it provides experimental support for Schultz's (1965) sensoristatic model of the nervous system.

The second project is concerned with studying the nature of intra-modal effects, a topic about which very little is known. In this work, the objective is to determine the functional status of the visual modality *per se* when it is deprived of visual stimulation for a prolonged period of time. Will its performance show an improvement similar to that observed in the non-deprived modalities? It is this latter topic which is being investigated in this thesis. However, in contrast to the previous Manitoba research which employed a monocular deprivation technique the present experiment will utilize a condition of binocular deprivation.

CHAPTER II

HISTORICAL BACKGROUND

For organizational purposes, this review of the literature will be presented under two main headings. The first will be concerned with an overview of a series of recent studies in which the critical flicker frequency (CFF) was measured after various durations of monocular deprivation. The second section will describe the relatively limited literature on the effects of binocular deprivation on the CFF.

Effect of Monocular Deprivation on the CFF

Although the technique of monocular deprivation has been used for many years by ophthalmologists (e.g., Adler, 1962; Lyle & Wyber, 1967) in the treatment of such visual disorders as strabismus and amblyopia, particularly in young children, virtually no experimental research has been directed at determining the nature of visual sensitivity in the non-occluded eye. Will this eye show a compensatory improvement in acuity as a result of prolonged disuse of the other eye or will some other type of effect be produced? In an attempt to throw some light on this question, a series of studies have been conducted at the University of Manitoba in which the CFF, a measure of temporal visual acuity (Geldard, 1972), was determined in adult subjects, with normal vision, at periodic intervals during both short and long periods of monocular deprivation.

The main objective of Experiment I (Bross & Zubek, 1972) was to determine the changes in the CFF after prolonged visual deprivation of the dominant eye. In this study, 28 male university students were subdivided into an experimental and control group, each containing 14 subjects. The experimental subjects were required to live, in groups of two, for a period of one week in a large windowless room (3.66 m x 14.02 m) which was furnished with sofas, chairs, study desks, and contained such facilities as a radio, television set, various games, and reading material of their choice. During the entire period, the subjects wore a black opaque mask over the dominant eye. Periodic checks were made to ensure that there were no light leaks. The control subjects, on the other hand, were not confined to these "apartment-like" quarters, but merely came to the laboratory on two occasions, a week apart.

A 15-minute period of dark adaptation was imposed upon both groups of subjects prior to the CFF determinations which were taken before and after one week. The stimulus consisted of a white light, at an initial flicker frequency above fusion, which was presented monocularly. The angular subtense of the centrally fixated stimulus was $2^{\circ}10'$, a value assuring full foveal stimulation. The descending method of limits was used, the subjects' task being to report the first indication of flicker.

The results revealed no statistically significant pre-post differences in the mean CFF of either eye of the control group or of the occluded eye of the experimentals. However, the nonoccluded eye showed a significant improvement of 2.47 cps ($p < .001$). Furthermore, all of the experimental subjects showed an improvement in visual performance, with the individual gains ranging from 0.87 to 5.62 cps.

Experiment II, employing 10 experimental and 10 control subjects, was a replication of the first except that the non-dominant or weaker eye was occluded for a week (Bross & Zubek, 1972). Again, the results indicated no change in either eye of the controls or in the occluded eye of the experimental group. A mean improvement, however, of 1.84 cps ($p < .01$) was observed in the nonoccluded eye. All subjects, but one, showed the effect with the individual gains ranging from 0.87 to 4.50 cps. Thus, essentially similar results were obtained regardless of which eye was occluded.

Since in the two earlier studies the CFF measurements were restricted exclusively to the pre- and post-experimental period, a third study was conducted whose purpose was to determine the temporal course of development of this facilitatory phenomenon in the nonoccluded eye (Bross & Zubek, 1972). Sixteen experimental subjects (dominant eye occluded) and the same number of controls were tested at intervals of 0, 1/3, 1, 2, 3, 5, and 7 days, each session being preceded by 15 minutes of dark adaptation. Relative to the control subjects who showed no changes in the CFF, at any duration, the nonoccluded eye of the experimentals revealed a negatively accelerating improvement in visual performance as a function of increasing duration of monocular deprivation. Furthermore, significant differences between the two groups were obtained at all durations (p's $< .001$), except at 0 and 8 hours.

The purpose of Experiment IV, in which the duration of monocular deprivation was extended to 14 days and a 14-day follow-up period was introduced, was two-fold (Zubek & Bross, 1973a). First, will the performance of the nonoccluded eye continue to improve during the second week or will it begin to decline towards the baseline, an effect which might occur as a result of the subject's adaptation to the novelty of the experimental condition? Second, what is the duration of the after-effects following termination of the monocular deprivation condition?

The CFF of the nonoccluded eye of the experimental subjects was determined at intervals of 0, 1, 3, 5, 7, 9, 11, and 14 days of monocular deprivation (dominant eye). Subsequently, the black patch was removed and the subjects were permitted to go home. However, they were required to return to the laboratory periodically for follow-up tests, the CFF being taken from the same test eye on post-deprivation days 1, 3, 5, 7, and 14. A group of 8 non-confined control subjects were tested concurrently during the 28-day period. The results indicated a negatively accelerating increase in the CFF of the nonoccluded eye during the first 7 days, thus confirming the results of Experiment III, a plateau from days 7 to 9, and finally a "step-like" increment of approximately 1 cps on day 11, an increment that was maintained at this higher plateau on day 14. Furthermore, _after_ the termination of monocular deprivation, the magnitude of the interocular improvement gradually decreased with time. However, it was still evident to some degree 14 days later, indicating that this facilitatory phenomenon is of a long-lasting nature. On the other hand, the CFF of the corresponding eye of the control subjects showed no changes during the entire 28-day test period.

In view of this unusual temporal pattern, the CFF of the _occluded_ eye in eight additional subjects was measured during and after 14 days of monocular deprivation, particularly to determine whether a compensatory decrease or depression of the CFF of the occluded eye might occur during days 11 to 14, the interval which displayed the "step-like" improvement in performance of the nonoccluded eye. In this study, no changes in CFF were observed at any test period either during or after the termination of monocular deprivation. These results, together with those obtained in Experiments I and II, clearly indicate that the CFF performance of the occluded eye is not affected by prolonged periods of visual deprivation.

This demonstration, in four experiments, of a significant increase in the CFF of the nonoccluded eye is puzzling in the light of some apparently contradictory results reported by Allen (1923) and Hollenberg (1924). After placing a black patch over the left eye for 3 hours, Allen measured the CFF of the right eye and then compared the results with those derived from the same subject when his left eye was not occluded. The results indicated a decrease in the CFF of the nonoccluded eye, relative to the control condition, for 15 different test stimuli ranging from 410 mu to 750 mu. These data were subsequently confirmed by Allen's assistant, Hollenberg (1924). Unfortunately, in neither study was the occluded eye tested nor was a deprivation duration longer than 3 hours employed.

Experiment V was conducted in an attempt to resolve these contradictory results and, in particular, to ascertain the possibility that brief durations of monocular deprivation may decrease the CFF and long durations result in an increase, a finding which could reconcile the two sets of data. In this study (Zubek & Bross, 1972), a black patch was placed over the dominant eye of 15 experimental subjects for a period of 24 hours. The CFF of the nonoccluded eye was then determined at intervals of 0, 3, 6, 9, 15, and 24 hours of monocular deprivation. These results were then compared with those obtained from the corresponding eye (non-dominant) of 15 controls who were confined for 24 hours in the same "apartment-like" quarters as were the experimentals, thus ensuring the same environmental and dietary conditions for both groups of subjects. Subsequently, another group of 9 subjects was added for the purpose of studying the changes in the occluded eye which previously had not been tested.

Although there were no changes in the CFF of the occluded eye at any test period, the CFF of the nonoccluded eye showed a significant decrease at both 3 and 6 hours, thus confirming the 50-year old results of Allen and Hollenberg, a reversal towards the baseline at 9 hours, and finally a significant increase at 24 hours, a finding consistent with Experiments III and IV. No changes in CFF were present in the confined control subjects. Further research indicated that this unusual interocular effect, which is referred to as the "depression-enhancement" or D-E phenomenon, is also present in the dominant, nonoccluded eye, its temporal pattern is not affected by the use of 30 rather than 15 minutes of dark adaptation, and finally, it can be obtained even when the subject is awake during the entire 24-hour period.

The purpose of the final experiment (Zubek & Bross, 1973b) was to determine whether the D-E phenomenon resulted from an absence of patterned vision or whether it was due to an absence of visual stimulation _per se_. (The darkness condition involves both variables.) In this 3-day study, employing 14 experimental and 14 confined control subjects, a white translucent patch was placed over one eye, thus producing a Ganzfeld-like condition of diffuse, homogeneous illumination. The CFF of the nonoccluded eye of the experimentals and the corresponding eye of the controls was then measured at intervals of 0, 3, 6, 9, 15, 24, 48, and 72 hours. No significant differences between the two groups were obtained at any temporal period. Furthermore, no trend towards either a depression or an enhancement of the CFF in the nonoccluded eye was observed. Negative results were also obtained in a follow-up study in which the occluded eye was tested during a 3-day period. Thus, the results of Experiment VI indicated that the D-E phenomenon resulted from an absence of visual stimulation rather than an absence of pattern vision, a finding of considerable theoretical importance.

In an attempt to provide a physiological explanation of this unusual D-E phenomenon, Zubek and Bross (1972) have proposed that "its unusual time course, together with the persistence of the phenomenon for many days, suggests the disturbance of some interocular mechanism in the higher levels of the visual system. We believe that prolonged monocular deprivation may be producing changes in certain areas of the primary sensory system, changes similar to the denervation supersensitivity that occurs in the higher neural centers after partial surgical deafferentation at lower levels of the central nervous system (Cannon & Rosenblueth, 1949; Stavraky, 1961). For example, Spiegel and Szekely (1955) reported that lesions in the posteroventral nucleus of the thalamus (relay nucleus for touch) are followed, after an initial period of depression of the somesthetic cortex, by a hyperexcitability of this region. (More than a century ago, Marshall Hall (1841) observed that "the first effect of injury done to the nervous system is a diminution of its functions, whilst the second or ulterior effect is the augmentation of these functions".) Occlusion of one eye, therefore, may be producing a state of tempory partial deafferentation of the visual system, a condition that is reflected behaviorally in the production of our CFF phenomenon. However, in contrast to surgically induced deafferentation, this deafferentation is functional, that is, it is produced by depriving the normal, intact organism of <u>some</u> of its accustomed visual experience."

"This hypothesis is consistent with Sharpless's (1964) revision of the Law of Denervation (Cannon & Rosenblueth, 1949), which has as its main thesis that supersensitivity results from prolonged disuse of neural pathways. Sharpless states, "Disuse may be the result of drugs, <u>privation of sensory experience</u>, or, most commonly, injury produced by severence of nervous pathways. Further, he states that supersensitivity is a compensatory process that occurs as a consequence of a radical and sustained change in the level of input to an excitable structure (p. 1047)."

If, as has been suggested, the D-E phenomenon falls in the same general category as the supersensitivity effects which result from partial surgical deafferentation of lower sensory systems, one would predict that it should not occur during binocular deprivation, a condition representing total functional deafferentation of the visual modality. This prediction will be tested in this thesis.

<u>Effect of Binocular Deprivation on the CFF</u>

A survey of the literature indicates that most of the studies pertaining to changes in the CFF during binocular deprivation have employed a condition of perceptual deprivation (PD), a condition in which the subject is not only visually deprived (by the use of translucent goggles) but is also exposed to a constant white noise and a reduction in the amount of cutaneous and kinesthetic stimulation.

In the earliest of these studies, conducted at McGill University, no significant changes in the CFF were observed during 3 days of PD (Doane, et al., 1959). Similar negative results have been reported after 2 to 6 hours of PD (Leiderman, 1962) and after 14 days of PD (Zubek, 1964). The only contrary result has been reported by the Japanese investigator Nagatsuka (1965) who observed a significant decrease (poorer visual acuity) in the CFF after 24 hours of PD. This latter finding, however, is questionable since a subsequent replication at the same laboratory failed to find any change in CFF (Kikuchi et al., 1969).

On the basis of these PD results it would appear that neither short nor long durations of binocular deprivation affect the CFF. This conclusion, however, is open to question since the data were derived from a procedure employing multimodal deprivation rather than visual deprivation alone. Furthermore, an examination of these studies reveals that the CFF was always administered as part of a lengthy battery of tests, thus raising the possibility of order and interaction effects.

Only two studies have investigated the effects of binocular deprivation alone on the CFF. Unfortunately, the results appear to be contradictory. In the first, conducted at Manitoba, Duda (1965) determined the CFF in 15 subjects before and after 7 days of darkness. No significant pre-post difference was obtained. A group of 15 non-confined controls, tested concurrently, also showed no change in the CFF. In contrast to these negative results, Gibby, Gibby and Townsend (1970) recently reported an increase in the CFF after a very brief period of binocular deprivation.

In this study 60 volunteers were subdivided equally into two experimental and one control group. Experimental group I was exposed to 3 hours of a Ganzfeld-like condition of diffuse, homogeneous illumination (translucent goggles) while experimental Group II was kept in darkness (opaque goggles) for the same duration. The data indicated that both experimental conditions produced a significant increase in the CFF, and of approximately the same magnitude, 3 hours later. The control group showed no change.

One possible explanation of these apparently contradictory results is that an initial compensatory improvement in the CFF may occur shortly after the onset of binocular deprivation and then gradually dissipate with time such that by 7 days (Duda's testing time) no facilitatory effect is evident. Some support for this interpretation is provided in the sensory deprivation literature where several instances of differential "time" effects have been reported (see Zubek, 1969a). For example, Vernon et al. (1959) demonstrated a significant improvement on a mirror tracing task at 48 hours but not at 24 or 72 hours of binocular deprivation and silence. However, because of several serious methodological deficiencies in the Gibby study, which will be described later, this investigation is open to question.

Although it would appear from this review of the literature that the CFF probably will not be affected by binocular deprivation periods of several days or longer, considerable uncertainty pertains to the effects of durations from 3 to 24 hours. As has been noted, increases, decreases, as well as no changes in the CFF have all been reported. In view of the inconclusive nature of this literature, it was felt that a study should be conducted to determine the changes in the CFF during 7 days of binocular deprivation, the tests being administered at durations similar to those employed at the various laboratories, e.g., at 3 and 6 hours and at 1, 3, and 7 days. In addition, since the previous experiments have employed darkness as well as diffuse, homogeneous illumination, both of these conditions will be used in this study.

CHAPTER III

EXPERIMENTAL METHOD AND RESULTS

Method

Subjects

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

The subjects were required to live, in groups of two, for 7 days, in a furnished windowless room (3.45 m x 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. Furthermore, they were provided with meals in their room and were allowed approximately 8 hours of sleep each night.

During the entire period, one of the experimental groups wore a black opaque mask over both eyes while the other wore a white translucent mask which produced a Ganzfeld-like condition of diffuse, unpatterned vision. The average illumination under the white mask, at sitting height, was approximately 20 ft. candles. 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.

Test Procedure

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

The monocular CFF of each subject was determined at intervals of 0, 3, 6, 9, 15, 24, 48, 72, 120, and 168 hours, each of the ten test sessions being preceded by 20 minutes[1] of bincoular dark adaptation and a meal or a 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 only necessary at the beginning of the experiment (0 hours). 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 minutes on the successive occasions. The measurements were taken in a room adjacent to the living quarters.

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[1]A 20- rather than the usual 15-minute period of dark adaptation was employed in order to conform to the longer duration employed by Gibby et al. (1970). This difference, however, is unimportant since previous research has indicated that the D-E phenomenon is not affected by dark adaptation periods ranging from 15 to 30 minutes.

The stimulus consisted of a white light, at an initial flicker frequency above fusion, 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 angle subtended by the centrally fixated stimulus was $2^{\circ}10'$, a value assuring full foveal stimulation. The flicker generating apparatus (Grason-Stadler, model E622) was set at a light-dark ratio of 0.50 and a lamp current reading of 22.6 mA. Eight trials, each separated by a 5-second inter-trial interval, were presented to the dominant eye of one-half of the subjects and to the non-dominant or weaker eye of the other half. The descending method of limits was used, the subject's task being to report the first indication of a flickering sensation. The arithmetic mean of these 8 trials was taken as the descending CFF threshold for each subject.

Visual dominance was determined by a special viewing device--the R.O. Gulden 17. Since the data indicated the presence of a similar proportion of right-eye and left-eye dominant subjects in all three groups, the results from the two eyes were pooled for purposes of statistical analysis.

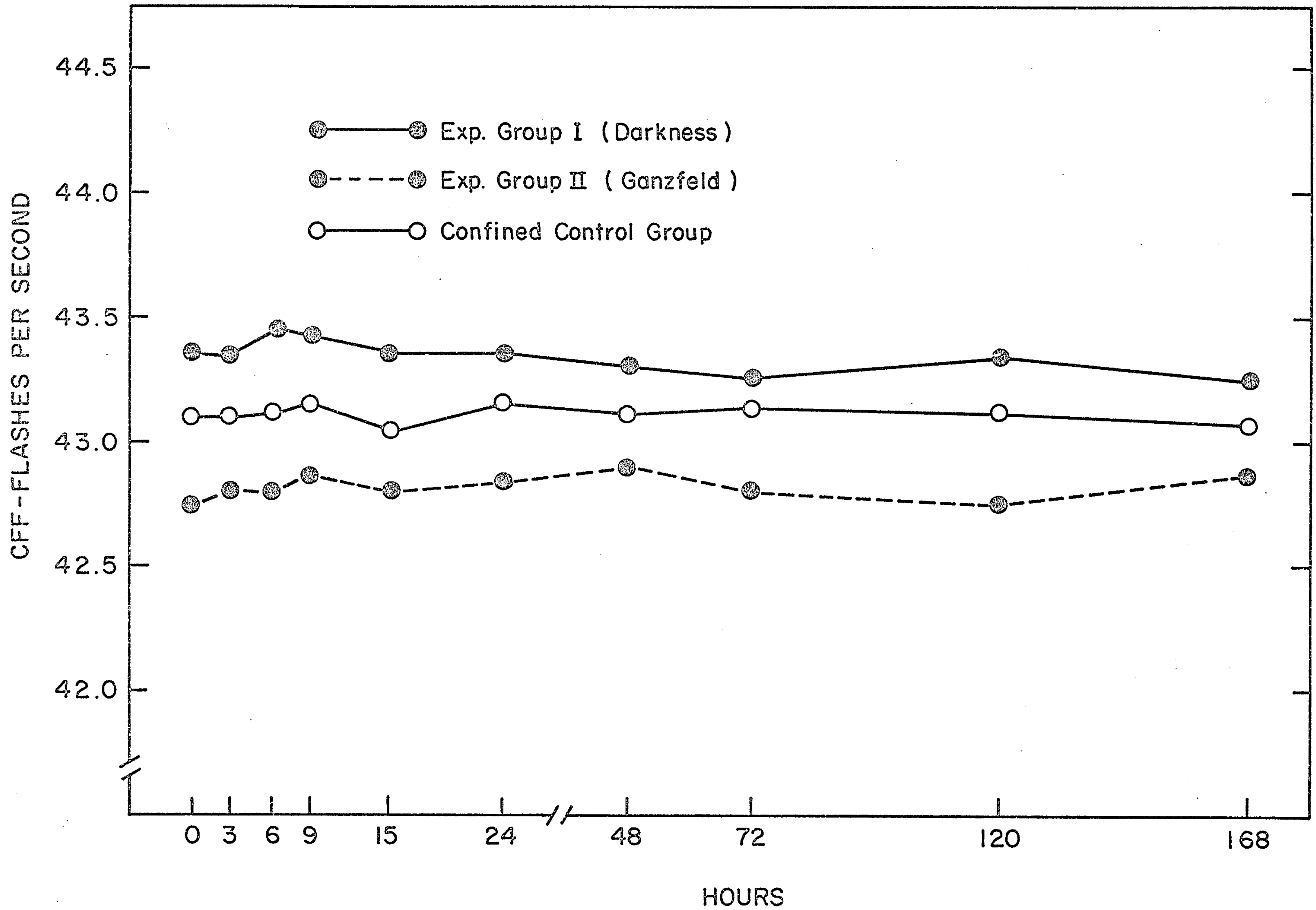
Results

Figure 1 summarizes the results obtained from the two experimental and one confined control group. It can be seen that the CFF performance of the three groups of subjects is similar at all ten test periods. Furthermore, in neither experimental group is there any suggestion of a trend toward decreased performance at 3 and 6 hours or a trend toward improvement at 24 hours or later, a temporal pattern characteristic of the D-E phenomenon. Furthermore, this visual impression is confirmed by an analysis of variance (mixed design for repeated measures, Myers, 1966) which revealed no significant between-group effects, between-duration effects, or interaction effects (see Table I).

TABLE I

Summary of Analysis of Variance, Mixed Design

Source	df	SS	MS	F	p
Group	2	15.9464	7.9732	< 1	n.s.
Error 1	33	3139.9966	95.1514		
Duration	9	0.3580	0.0398	< 1	n.s.
Group x Duration	18	0.6056	0.0336	< 1	n.s.
Error 2	297	118.4311	0.3988		



Exp. Group I (Darkness)
Exp. Group II (Ganzfeld)
Confined Control Group
CFF-FLASHES PER SECOND
44.5
44.0
43.5
43.0
42.5
42.0
0
3
6
9
15
24
48
72
120
168
HOURS

CHAPTER IV

DISCUSSION

The results of this study indicate that visual performance, as measured by the CFF, is not affected at any temporal period during one week of binocular deprivation. This was found to be true regardless of whether darkness or a Ganzfeld-like condition of homogeneous illumination was employed.

These negative results are consistent with virtually all of the studies which have previously investigated the effect of visual deprivation on the CFF. They are consistent with the perceptual deprivation (PD) experiments of Leiderman (1962), Kikuchi et al. (1969), Doane et al. (1959), and Zubek (1964), all of which failed to demonstrate any significant changes in the CFF after 2 to 6 hours, as well as 1, 3, and 14 days of binocular deprivation and constant white noise. They are also consistent with the series of Manitoba studies in which the CFF of the occluded eye was not altered by various durations (3 hours to 14 days) of either darkness or homogeneous illumination. Finally, these results confirm Duda's (1965) finding that a one-week duration of binocular deprivation alone (darkness) has no effect on the CFF as measured at the end of the experimental period. In addition, they extend his negative finding to include the condition of homogeneous illumination.

However, the failure in this study to demonstrate a significant increase in the CFF after 3 hours of either darkness or a Ganzfeld condition is contrary to the results obtained by Gibby, Gibby, and Townsend

(1970) in their binocular deprivation experiment. These investigators reported a significant increase of 2.2 cps after 3 hours of a Ganzfeld condition and an increase of 1.8 cps after a similar duration of darkness. No significant difference in the CFF was observed in the control group. However, an examination of the procedure employed by Gibby et al. reveals two serious methodological deficiencies which may account for these apparently contradictory results.

First, rather than employing a standard and customary viewing chamber the investigators required their subjects to observe the CFF test stimulus from a reclining couch located 3.05 meters from the light source. Under such a viewing condition it is difficult to keep constant such important variables as locus of retinal stimulation, head movements, and level of illumination all of which are known to effect the CFF (Brown, 1965). It is possible, therefore, that this lack of control over the testing environment may have acted in some systematic manner to produce the reported results.

A second, and perhaps more important methodological deficiency pertains to the inadvertent introduction of silence into the treatment of the two experimental groups. In this study, the procedure was such that all three groups were tested at two sessions, one week apart. The initial or pre-session was the same for all subjects and consisted of 20 minutes of dark adaptation and the administration of the CFF as well as several auditory tests. This same procedure was then repeated on the post-session a week later but only for the control group. On the other hand, the two experimental groups were required to wear padded earphones for a 3-hour period in addition to being exposed to the same duration of darkness or the Ganzfeld condition. (It is important to note that in the initial session the earphones were only worn during the brief period required to administer the auditory measures.) Furthermore, the experimenters refrained from talking to the subjects during their second session. Thus, it is evident from the procedure employed that an inadvertent condition of relative silence of 3 hours duration was added to the binocular deprivation situation. It is conceivable, therefore, that the presence of auditory deprivation in both experimental groups was the factor responsible for producing their superior CFF performance. Some support for this hypothesis has recently been provided in an unpublished Manitoba study in which silence *per se* was shown to produce a significant increase in the CFF.

A third possible explanation unrelated, however, to Gibby's experimental procedure pertains to the operation of a differential expectancy or set in the subjects of the two studies. Some evidence for the importance of this variable has been provided by Zubek, Shephard, and Milstein (1970) who reported that the magnitude of EEG changes (slowing of the alpha wave activity of the brain) observed during sensory isolation appears to be related to what the subjects are told beforehand as to the expected duration of the experiment. Since in the Gibby study the subjects were told in advance that the duration would be only 3 hours while in the present experiment they knew it would be one week, it is evident that the expectancy or set of the two groups of subjects was different. In an attempt to determine whether this particular variable could possibly account for the contradictory results, Harper and Zubek recently completed a study (unpublished) in which the CFF was determined in 14 experimental subjects before and after 3 hours of binocular deprivation (darkness) and in 14 confined control subjects over the same test period (their expectancy, therefore, was the same as in the Gibby study). Each determination of the CFF was preceded by 20 minutes of dark adaptation, a duration similar to that employed by Gibby. However, unlike his procedure a standard viewing chamber was again employed. The results revealed a decrease of 0.34 cps in the experimental group and an increase of 0.08 cps in the controls. An analysis of variance indicated that the results were not statistically significant.

On the basis of the negative results obtained in this follow-up study, together with the presence of the two methodological deficiencies in the Gibby experiment, it is probably safe to conclude that this isolated instance of superior CFF performance resulted from some experimental artifact.

Finally, the results of this experiment are important in three main respects. First, they have conclusively demonstrated that performance on the CFF is not affected by various durations of binocular deprivation involving either darkness or homogeneous illumination, a finding about which there were some doubts. Second, since the D-E phenomenon was not observed, as predicted, during total visual deprivation, further evidence has been provided to support Zubek and Bross's hypothesis that this unusual visual effect falls in the same general category as the denervation supersensitivity phenomena which are known to occur after partial surgical deafferentation of the lower primary sensory systems. Third, this experiment as well as the previous ones on monocular deprivation raise the important question as to whether the specific results which have been obtained to date are dependent upon the use of the CFF, a measure of temporal visual acuity or the resolving power of the eye, or whether they can also be obtained with other types of visual tasks which do not involve intermittant stimulation e.g., various measures of spatial visual acuity (Vernier acuity, Landolt ring, etc.) and brightness discrimination. Future research along these lines would be useful, particularly in determining the specificity or generality of the D-E phenomenon.

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APPENDIX - RAW DATA

TABLE I

Experimental Group I (Darkness Condition): Mean CFF at Ten Temporal Periods

Subject	Duration (Hours)									
No	0	3	6	9	15	24	48	72	120	168
1	43.750	47.250	42.375	46.375	45.750	42.250	46.125	42.750	46.250	42.500
2	45.625	42.875	45.250	43.250	43.000	46.500	41.750	45.750	43.125	43.625
3	42.875	42.750	42.125	43.875	43.500	41.250	43.125	41.750	43.875	41.750
4	42.625	45.375	42.875	46.375	46.250	40.750	46.875	41.500	46.875	42.250
5	43.750	44.250	46.000	42.625	43.625	46.125	42.375	45.250	42.500	46.000
6	39.625	39.250	39.000	39.375	40.000	40.250	40.125	40.125	39.875	40.000
7	37.750	40.000	39.000	40.250	40.125	40.000	40.000	40.125	40.125	39.875
8	43.500	45.125	44.375	46.500	42.625	42.875	45.625	41.875	46.000	42.750
9	44.875	42.750	45.750	43.250	42.625	46.625	42.625	47.625	42.000	46.875
10	44.375	44.875	43.500	41.625	41.250	44.125	42.250	43.000	42.375	44.125
11	42.500	42.875	42.875	45.250	45.500	43.500	46.625	43.125	44.500	43.125
12	48.625	42.750	47.500	42.500	41.625	46.000	42.125	46.375	42.750	46.250
Mean	43.323	43.344	43.469	43.438	43.344	43.354	43.302	43.271	43.354	43.260

TABLE II

Experimental Group II (Ganzfeld Condition): Mean CFF at Ten Temporal Periods

Subject No	Duration (Hours) 0	3	6	9	15	24	48	72	120	168
1	42.875	43.000	42.750	43.250	49.000	49.250	49.875	49.750	50.250	43.125
2	46.250	46.250	46.500	46.000	41.750	41.625	42.000	42.250	42.250	46.625
3	38.625	38.625	38.750	38.500	39.875	39.625	39.500	39.500	39.625	37.750
4	43.125	42.625	42.625	42.625	40.000	40.375	40.375	40.500	39.875	42.125
5	45.500	45.375	45.625	45.000	40.000	40.000	40.000	39.375	39.125	45.625
6	47.000	46.750	46.250	46.375	41.000	40.875	40.750	40.500	40.375	46.125
7	39.250	41.125	40.875	41.375	46.000	46.625	46.375	46.250	46.250	40.625
8	40.250	40.250	40.125	40.375	45.750	45.625	45.625	45.750	45.875	40.000
9	40.000	39.875	39.750	39.875	42.750	42.500	41.625	41.625	42.500	40.000
10	39.500	39.500	39.375	39.375	38.000	37.625	37.875	37.250	37.375	39.875
11	42.000	41.875	41.750	41.875	46.125	46.625	47.625	47.625	47.125	42.250
12	48.500	48.625	49.625	49.375	43.500	43.375	43.375	43.500	42.500	50.500
Mean	42.740	42.823	42.833	42.875	42.813	42.844	42.917	42.823	42.760	42.885

TABLE III

Confined Control Group: Mean CFF at Ten Temporal Periods

Subject No	Duration (Hours) 0	3	6	9	15	24	48	72	120	168
1	45.000	45.125	45.125	44.875	45.125	45.125	45.375	45.000	45.125	44.875
2	46.000	45.625	45.250	44.250	38.250	44.750	43.750	42.875	42.750	37.375
3	43.750	43.250	42.750	43.250	39.000	42.500	42.500	43.375	43.250	39.125
4	42.375	42.375	42.625	42.625	45.750	41.875	42.125	42.250	41.125	45.500
5	47.625	47.500	47.125	46.875	45.500	47.500	47.500	47.250	47.375	45.875
6	41.250	41.875	42.250	42.125	46.750	42.000	41.750	41.875	41.750	47.125
7	47.125	47.000	46.875	46.375	42.000	47.000	47.250	47.250	47.375	42.500
8	46.500	46.375	45.250	45.000	47.000	45.375	46.000	46.125	46.250	47.375
9	45.500	45.500	45.625	45.875	41.875	45.125	45.125	45.625	45.625	41.000
10	36.125	36.250	37.375	38.375	42.500	38.750	38.250	38.375	39.125	44.000
11	35.625	36.750	38.125	38.500	43.875	37.875	37.625	37.625	37.625	42.125
12	40.375	39.500	38.875	39.750	39.500	40.375	40.125	40.250	40.000	40.000
Mean	43.104	43.094	43.104	43.156	43.052	43.188	43.115	43.156	43.115	43.073