EFFECTS OF PROLONGED MONOCULAR DEPRIVATION ON THE CFF IN THE OCCLUDED AND NON-OCCLUDED EYE

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ABSTRACT

EFFECTS OF PROLONGED MONOCULAR DEPRIVATION ON THE CFF
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The purpose of this thesis was to determine whether a significant improvement in visual sensitivity, as measured by the CFF, can be demonstrated after a prolonged period of visual deprivation (darkness). Although the scanty literature on this topic, using a binocular deprivation procedure, has yielded negative results, it is possible that a facilitatory effect might be obtained if a monocular deprivation technique was to be employed, especially if the measurements were to be taken from the non-occluded eye. Using this type of experimental procedure, a compensatory improvement in visual sensitivity in the normal eye might have an opportunity to develop. This use of the non-isolated eye is somewhat analogous to the employment of auditory and cutaneous measures in the binocular deprivation experiments where neither of these measures involves a receptor field that has undergone sensory restriction. These studies, as the literature indicates, have demonstrated a variety of inter-sensory facilitatory effects.

Two experiments were conducted in which the CFF of the occluded and non-occluded eye was determined before and after one week of monocular deprivation (darkness). No significant changes occurred in

the occluded eye, but a significant increase in the CFF of the non-occluded eye was present, an improvement which occurred regardless of whether the dominant or non-dominant eye was visually deprived. In a third experiment, in which the CFF of the non-occluded eye was determined at intervals of 0, 1/3, 1, 2, 3, 5, and 7 days of monocular deprivation, a negatively accelerating improvement in performance, as a function of duration, was observed. Furthermore, some evidence was obtained which indicated that this enhancement phenomenon was still present, to a noticeable degree, one week after the removal of the occluding eye patch. Finally, an exploratory study, of one day's duration, was conducted, the CFF being measured at intervals of 0, 3, 6, 9, 15, and 24 hours of monocular deprivation. The results on the non-occluded eye revealed an initial depression in visual sensitivity, with the maximum occurring at 6 hours, followed subsequently by a pronounced enhancement effect. The findings of this series of experiments were related to the denervation supersensitivity phenomenon of Cannon and Rosenblueth (1949).

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CHAPTER I

THE PROBLEM AND INTRODUCTION

Statement of the Problem

During the past seven years, a series of studies conducted at the University of Manitoba have demonstrated that a one-week period of visual deprivation (binocular) can produce a significant improvement on various measures of cutaneous, auditory, olfactory, and gustatory sensitivity, effects which persist for several days after the termination of visual deprivation. Although pronounced inter-sensory facilitatory effects have been reported, virtually no attention has been paid to the functional status of the visual modality itself. Will this modality, deprived of stimulation for a prolonged period of time, also show an increase in sensitivity? This is an important question, particularly since it has already been shown that a prolonged period of tactual deprivation of a restricted area of the skin can produce a significant increase in tactual acuity and in absolute pressure sensitivity.

Although the scanty literature on this problem, using a binocular deprivation procedure, has provided no evidence for an improvement in visual sensitivity, it is possible that positive results might be obtained if a monocular deprivation technique was to be employed, especially if the measurements were to be taken from the non-occluded eye. Using this type of experimental procedure, a compensatory improvement in visual sensitivity in the non-deprived eye might have an opportunity to develop. Some support for this hypothesis has been provided by the literature on therapeutic ophthalmology in which the prolonged application of a patch over one eye can, in certain cases, produce a beneficial effect in the other eye.

The purpose of this thesis is to determine (a) whether a significant improvement in the resolving power of the eye, as determined by the CFF, can be produced by a monocular deprivation procedure and (b) if present, what is it's temporal course of development during a one-week experimental period?

Introduction

The first experimental work on sensory restriction was initiated at McGill University in the early 1950's (Bexton, Heron, & Scott, 1954). Since this pioneer research, considerable interest has been shown by investigators from various disciplines in the study of the effects of a reduction in the level and variability of visual, auditory, and tactual-kinesthetic stimulation. A summary of the experimental literature, which presently numbers approximately 1,300 publications (see Zubek, 1969a for a review of this literature), reveals that a wide range of behavioral and physiological processes have been investigated. Some of the topics that have been studied are sensory and perceptual-motor processes, biochemical and EEG changes, stimulus-seeking behavior, cognitive abilities, attitudinal changes, hallucinatory phenomena, affective disturbances, and personality functioning.

Two general procedures have been used in the investigation of these various phenomena. In the first of these, sensory deprivation (SD), the objective is to reduce all sensory stimulation to a minimum through the use of earplugs, dark binocular masks, cardboard gloves, and as little physical movement as possible. In the second procedure, perceptual deprivation (PD), the purpose is to reduce patterned sensory stimulation while maintaining an essentially normal level of sensory input. This is usually accomplished by providing a constant masking sound (white noise or hum of fan) and covering both eyes with translucent goggles or a white cloth mask which permits diffuse light but eliminates pattern vision. In experiments utilizing these two procedures (SD or PD), or modifications of them, the subjects are deprived of stimulation for various periods of time ranging from as short as five minutes to prolonged intervals of up to fourteen days.

Of the various phenomena which have been demonstrated by these multi-modality deprivation procedures, perhaps the most intriguing have been the reports of sensory facilitatory effects, i.e., an improvement in sensory functioning. The existence of these phenomena was an unexpected finding since most investigators believed that sensory isolation should produce impairments rather than improvements in performance.

The first demonstration of a facilitatory effect was observed at McGill (Doane et al., 1959). Subjects who were exposed to 2 and 3 days of PD showed a significant improvement in tactual acuity as measured by the two-point threshold technique. These positive results were subsequently confirmed by two Japanese studies, both employing two days of PD (Nagatsuka & Maruyama, 1963; Nagatsuka & Suzuki, 1964) and by a Manitoba PD-study of one-week's duration (Zubek, 1964b). This cutaneous phenomena, it is important to note, was shown by virtually all of the experimental subjects in the various studies. In addition to these findings, the literature has also indicated that prolonged periods of sensory restriction can produce an increase in pain sensitivity (Vernon, 1963; Vernon & McGill, 1961), taste sensitivity (Nagatsuka, 1965), and an improvement on an auditory vigilance task (Myers, et al., 1962).

In an attempt to clarify the nature of these facilitatory phenomena resulting from multi-modality deprivation, two general approaches have recently been employed. The first, which represents the bulk of the literature, is concerned with determining whether these phenomena can be produced by the deprivation of only one modality e.g., vision, while the second is concerned with the problem of whether facilitatory effects can be demonstrated within a single, deprived modality. It is this latter approach which will be employed in this thesis.

CHAPTER II

HISTORICAL BACKGROUND

For organizational purposes this historical review will be presented under two main headings. The first will be concerned with a brief review of the experimental literature on the effects of prolonged deprivation of one modality (vision) on the functional status of other modalities. The second section will survey the limited research on the sensitivity of the deprived modality itself, reviewing studies on cutaneous, auditory, and visual deprivation. In this latter section, particular attention will be given to the ophthalmological literature in which eye patches have been used for therapeutic purposes.

Effects of Depriving One Modality (Vision) on the Functional Status of Other Modalities

In the introductory section, some experimental evidence was cited indicating that a significant improvement in tactual acuity, pain sensitivity, taste sensitivity, and in auditory vigilance can occur after a prolonged period of multi-modality deprivation. Recently, a series of studies conducted at the University of Manitoba have demonstrated that similar facilitatory effects can result from visual deprivation alone. In these experiments the subjects are placed, in groups of two, in an ordinary room equipped with comfortable furniture for a period of one week. Apart from the presence of constant darkness, their sensory environment is essentially normal. They are free to move about the room, to talk to one another, and to listen to a radio provided for them.

In the first study of this series (Zubek, Flye, & Aftanas, 1964) two measures of tactual acuity (two-point threshold and tactual fusion) were taken from the index-finger, palm, and forearm, before and immediately after a week of darkness, and subsequently at intervals of 1, 2, 3, 5, and 7 days. In addition, a dolorimeter was used to measure the heat and pain sensitivity of the forearm. The results revealed a significant increase in tactual acuity and in heat and pain sensitivity, an effect present in all experimental subjects and on all skin areas tested. Furthermore, these facilitatory effects persisted for several days after the termination of the experimental condition.

The purpose of the second experiment (Zubek, Flye, & Willows, 1964) was to determine whether effects similar to those of darkness could be demonstrated by a one-week exposure to diffuse, homogeneous illumination. This condition yielded an essentially similar pattern of results, indicating that these various cutaneous phenomena were produced by an absence of pattern vision rather than an absence of visual stimulation *per se*.

In the third study (Duda & Zubek, 1965), two types of auditory measures were administered before and after a week of darkness: auditory discrimination, using an auditory flutter technique (interrupted white noise), and the absolute threshold of hearing for five frequencies (100, 300, 1,000, 5,000, and 9,000 cps). The results showed a significant improvement on the auditory flutter fusion task which persisted for one day after the termination of darkness. Surprisingly, however, the absolute threshold of hearing was not affected, suggesting that auditory facilitatory effects may only occur on tasks involving temporal discriminations.

In the fourth experiment (Phelps & Zubek, 1969), a variety of other types of cutaneous and auditory measures were employed in order to determine the generality or specificity of these inter-sensory facilitatory effects. Briefly, these indicated a significant increase in absolute pressure sensitivity of the finger, forearm, neck, and leg, with the after-effects on certain skin areas persisting for several days after the termination of darkness. However, measures of tactual and auditory localization (absolute and differential) were not affected by the week of visual deprivation.

The final study of this series (Schutte & Zubek, 1967) was concerned with the determination of olfactory and taste sensitivity after a week of darkness. A significant increase in olfactory sensitivity (recognition threshold for benzene) was observed but with no persistence of after-effects. The measures of taste thresholds, on the other hand, yielded a differential pattern of results. While sensitivity to NaCl (salty) and sucrose (sweet) increased significantly, with the after-effects persisting for one day, sensitivity to HCl (sour) and quinine (bitter) was not affected to a statistically significant degree. However, a marked trend toward an improvement for sour was evident in 11 of the 12 experimental subjects, a proportion identical to that observed with salt and sucrose.

Since the measurements in these five Manitoba studies were confined exclusively to the pre- and post-experimental period, a second series of studies was initiated whose general purpose was to investigate the temporal course of development of some of the facilitatory phenomena. Specifically, the purpose was two-fold. First, will the optimal effects occur early in the one-week period and then diminish in magnitude, with time, as the result of a possible adaptation of the subject to the impoverished visual environment or will their temporal course be characterized by some other type of functional relationship? Second, what is the <u>approximate</u> minimum duration of visual deprivation (darkness) required to produce the various facilitatory effects?

In an attempt to provide some answers to these important questions, Milstein and Zubek (in press) conducted two experiments in which a variety of cutaneous measures were taken from the forearm at intervals of 0, ½, 1, 2, 3, 5, and 7 days of visual deprivation. The results revealed no significant difference between the experimental and control subjects on measures of absolute pressure sensitivity, pain sensitivity, and the two-point threshold. However, a marked trend toward an improvement was evident, particularly after the third day of deprivation. This absence of significant facilitatory effects, especially at the <u>end</u> of the one-week period, is puzzling in the light of the earlier research from the Manitoba laboratory in which positive results were obtained. Since the main procedural difference was the introduction of interpolated testing in this particular experiment, it was suggested that the repeated testing of the <u>same</u> cutaneous area at frequent intervals could have produced central after-effects of a long-lasting nature, resulting in a cumulative adaptation or "habituation" effect. This phenomenon, conceivably, could suppress any facilitatory effects that would have occurred in its absence.[1]

In contrast to these negative findings, the results on a tactual fusion task (a measure of tactual acuity involving the presentation of interrupted puffs of air of increasing frequency) revealed a progressive improvement in performance up to the fifth day of deprivation with some indication, however, of a levelling off in performance on the seventh day. Since this facilitatory effect was already present, to a statistically significant degree, at the first test period (12 hours), a third study was conducted in which the tactual fusion task was administered at intervals of 0, 4, and 12 hours of visual deprivation. The results showed a significant improvement in performance after 12 hours but not after 4 hours, thus indicating that this phenomenon first appears somewhere between 4 and 12 hours of visual deprivation.

In attempting to account for the positive results on tactual fusion but not on the other three cutaneous tasks, Milstein and Zubek (in press) suggested that the answer may largely lie in differences in

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[1] This hypothesis was tested in a recently completed experiment at the University of Manitoba in which measures of pain and pressure sensitivity were administered at intervals of 0, 3, and 7 days of visual deprivation. The results indicated a significant increase in sensitivity, relative to a control group, on both measures and on both the third and seventh day. The two-point threshold was not administered because of its unreliability and considerable susceptibility to practise effects.

the stimulus characteristics of the measures which were employed. While the measures of two-point threshold and pressure and pain sensitivity are non-temporal in nature, the tactual fusion task, on the other hand, involves the performance of a series of temporal discriminations. Since different perceptual processes (and possibly different neural processes) are probably involved in the performance of these two types of tasks, it is conceivable that they may interact differentially with visual deprivation.

If, as has been hypothesized, the temporal discriminatory nature of the tactual fusion task is an important factor in accounting for the differential results, one might predict a similar progressive improvement in performance, with time, on other analogous types of tasks, e.g., on auditory flutter fusion which has been shown to improve after a week of visual deprivation (Duda & Zubek, 1965). Some support for this prediction has recently been provided at the Manitoba laboratory by Pangman (1970). In this study, measures of auditory flutter fusion were taken at intervals of 0, ½, 1, 2, 3, 5, and 7 days of visual deprivation. The results showed a progressive improvement in performance with time, a pattern of results very similar to those obtained by Milstein and Zubek. There was, however, one important difference pertaining to the minimum duration of deprivation required to produce the facilitatory effect. For tactual fusion the minimum duration was found to lie between 4 and 12 hours, whereas for auditory fusion a significant increase did not occur until the third day of deprivation. Thus, on the basis of the data obtained by these two groups of investigators it would appear that when sensory measures of a temporal discriminatory nature are employed, a progressive improvement in sensitivity will occur, a phenomenon similar in some respects to stimulus-seeking behavior which increases with time in SD (see Jones, 1969 for review of this topic).

These findings on cross-modal effects provide some experimental support for Schultz's (1965) sensoristatic theory which states that "when stimulus variation is restricted, central regulation of threshold sensitivity will function to lower sensory thresholds", a theory in which the reticular activating system plays an essential role. Furthermore, they show that some of the facilitatory effects produced by multi-modal deprivation can also occur under conditions of visual deprivation alone. Whether they will also occur after auditory deprivation alone remains to be determined.

Since the question as to what happens to the sensitivity of the deprived modality itself is of considerable importance, a review of the literature on this topic will now be presented.

Effects on the Sensitivity of the Deprived Modality

Tactual deprivation. The first work on this topic was conducted by Braunstein (1957) and Heron (1961) at McGill University. The investigators occluded the volar surface of the forearm with a perforated 3 x 6 cm. cup for a period of four days. Tests of absolute pressure sensitivity were then taken from the occluded area before and after the experimental period. A homologous area on the contralateral arm served as a control. In both exploratory studies, an increase in sensitivity was observed but it was not significant relative to that of the control arm. However, since the control area was homologous with the occluded area a confounding variable may have been introduced. If the effect is central, changes might occur in both the experimental and control area, thus masking the true effect.

As a check on this possibility, Heron and Morrison (unpublished research, cited by Zubek, 1969b) performed two experiments utilizing a slightly modified procedure. In the first study, the control area was changed to a more distal area (i.e., a non-homologous area) on the contralateral arm. As a result of this modification, a significant increase in tactile sensitivity in the isolated skin area, relative to the control area, was obtained, an effect which was shown by all experimental subjects. In the second experiment, the measure of pressure sensitivity was taken not only from the occluded area but also from two areas on the contralateral arm, one homologous and the other non-homologous. The data revealed a considerable increase in sensitivity in the occluded area but virtually no change in the non-homologous control area. The homologous area on the contralateral arm also showed a greater sensitivity but the change only bordered on statistical significance.

These early McGill results have been confirmed and extended by a series of three studies at the University of Manitoba, each involving a one-week period of skin occlusion. In the first experiment (Aftanas & Zubek, 1963a), a small perforated cup was attached to the volar surface of the forearm, 8 cm below the elbow. For comparative purposes, a control group wore an open plastic ring bandaged to the forearm. While measures of pain and heat sensitivity were not affected, all experimental subjects showed a significant increase in tactual acuity as determined by the tactual fusion method. In the second experiment, (Aftanas & Zubek, 1963b), not only was this facilitatory effect confirmed, but it was also shown to be long-lasting in nature, persisting for several days after the removal of the occluding cup.

In order to determine whether central or peripheral factors were responsible for producing this increase in tactual acuity, a third experiment (Aftanas & Zubek, 1964) was conducted whose purpose was to determine whether this facilitatory effect can also be observed on the contralateral limb. If it can be demonstrated on the non-experimental arm, central mechanisms would clearly be involved. As in the Heron and Morrison experiment, three skin areas were employed: an occluded area on one arm and a homologous and a non-homologous area on the contralateral arm. Two measures of tactual acuity (tactual fusion and two-point threshold)were administered before and immediately after the one-week experimental period. The results indicated that both measures showed a significant increase in tactual acuity in the occluded area as well as in the homologous area of the contralateral arm. However, no change occurred in the non-homologous area, indicating that the effect is quite specific.

In an attempt to explain the physiological basis of this phenomenon, Aftanas and Zubek (1964) state that the highly specific locus of these changes in tactual acuity appears to rule out the involvement of the reticular activating system. As a more viable alternative, they suggest that tactual deprivation probably produces changes in the central areas of the primary somesthetic system, similar in nature to the supersensitivity occurring in the sensory cortex following partial deafferentation at lower levels of the central nervous system, (Cannon & Rosenblueth, 1949; Stavraky, 1961). According to this hypothesis, stimulus deprivation of a localized area of the skin produces a state of temporary partial deafferentation of the somesthetic system but of a functional rather than of a surgical nature.

Auditory deprivation. The only relevant research in this area consists of two studies of a non-laboratory nature conducted by Rosen and his collaborators. The first report (Rosen et al., 1962) compared the auditory thresholds of a group of Mabaans, living in a relatively noise-free environment in a remote area of the Sudan, with that of a group of urban residents in the U.S.A. Thresholds for frequencies ranging from 500 to 6,000 cps were determined for 541 male and female Mabaans between the ages of 10 and 90, and a comparative sample in the U.S.A. The results revealed a striking superiority in hearing of the Mabaans relative to an urban population in the U.S.A., a difference which was particularly pronounced in the older age group. This superiority of the Mabaans was especially noticeable at the higher frequencies.

In the second study (Rosen et al., 1964), two modifications were made. First, the testing range was expanded to include frequencies between 12,000 and 24,000 cps, and second, for comparative purposes, similar tests were administered in New York, Düsseldorf, and Cairo.

Subjects were categorized by decades into groups, and over 100 males and females, ranging in age from 10 to over 70, were tested in each group. The results revealed that a definite indication of superior auditory acuity was already evident in the 10-19 age group, where the Mabaans out-performed the urban samples in the higher frequencies above 18,000 cps. In the next decade group, this divergence appeared at 14,000 cps, and continued for all subsequent age groups. Even in the 70-79 age group, 83 percent of the Mabaans were able to hear a tone of 12,000 cps, whereas in the city populations only 2 percent were able to do so. In discussing their findings, the investigators suggest that the progressive loss of hearing of high frequencies in urban populations is largely related to the noise level in the environment. This hypothesis is supported by their finding that in the Mabaans no sex differences in hearing loss were found. On the other hand, the males of the city populations, who are generally exposed to greater noise levels than females, show a greater loss of hearing with age.

Visual deprivation. Although the previous two sections have indicated that prolonged periods of either cutaneous or auditory deprivation can produce an increase in sensitivity in the restricted modality, this finding apparently does not apply to vision--at least in the studies employing binocular deprivation. In the only directly relevant study, conducted at Manitoba, Duda (1965) reported that a one-week period of darkness produced no significant effect on the CFF. Further evidence for this negative finding, but of an indirect nature, has been provided by a series of studies in which both visual and auditory deprivation was employed. In the earliest of these, conducted at McGill, no significant change in the CFF was observed after three days of PD (Doane et al., 1959). Similar negative results on the CFF have also been reported after 2 to 6 hours of PD (Leiderman, 1962), and after 14 days of PD (Zubek, 1964). The only contrary finding has been reported by Nagatsuka (1965) who observed a significant decrease in the CFF after 24 hours of PD.

Other types of visual measures have also failed to demonstrate an increase in sensitivity. For example, Doane et al. (1959) in a three-day PD study appraised visual acuity by means of a horizontal row of 14 black lines with each line in the series possessing a small gap of progressively decreasing width. Although an improvement in visual acuity was observed in the experimental relative to the control subjects, the difference was not statistically significant. Suzuki, Ueno, and Tada (1966), using a more accurate measure of visual acuity, the Landolt ring, also reported no significant change, but with a trend toward improvement, after one day of PD. Similar negative results on visual acuity, but without a trend, have also been reported by Gendreau et al. (1968) after a week of PD, and by Pollard, Uhr, and Jackson (1963) after 8 hours of PD.

From this review of the literature it appears that an increase in sensitivity can occur within the deprived cutaneous or auditory modality but apparently not within the visual modality. One possible reason for this discrepancy may be the fact that complex chemical changes are taking place in the visual system after occlusion, a condition which does not apply to the other two deprived modalities. This conceivably could produce differential effects. A second possibility pertains to the observation that previous studies have employed a condition of binocular deprivation where both eyes are exposed to constant darkness or homogeneously illuminated fields. These conditions, however, do not necessitate any compensatory reaction since both eyes are exposed to constant conditions, and hence no adjustments of the visual system are required. It is possible, therefore, that a compensatory facilitatory effect might be demonstrated if the visual deprivation was confined to only one eye, and more specifically, if the visual measures were to be taken from the non-occluded eye. This use of the non-occluded eye is somewhat analogous to the employment of auditory and cutaneous measures in a visual deprivation experiment where neither of these measures involves a receptor field that has undergone sensory restriction. This procedure, as the literature indicates, can produce pronounced facilitatory effects.

Some support for this hypothesis has been provided by the literature on therapeutic ophthalmology which indicates that the application of a patch over one eye may produce a beneficial or corrective effect in the other eye. For example, the authors of a current textbook on practical orthoptics state that "the value of occlusion (of one eye) cannot be over-emphasized. It serves the dual purpose of a preventative as well as a curative measure.....Ideally it should continue until the correct sensorial relationship is re-established". (Lyle & Wybar, 1967; pp. 236-237). Two widely accepted uses of the occlusion of one eye occur in the treatment of squint (strabismus) and anomalous retinal correspondence. In the treatment of squint, it is generally recommended that first one eye and then the other be occluded for a period of one to two weeks (e.g., Adler, 1962; Liebman & Gellis, 1966) until the strabismus is corrected. Similarly, in the case of non-corresponding focal points in the retinas (anomalous correspondence), the same procedure of alternating the occlusion of the eyes is used. Both of the above conditions have a common feature in that the cause of the maladjustment lies in organic disorders, viz., poor co-ordination of occulo-motor muscles or muscular mis-developments.

More directly related to the problem of a possible improvement in sensitivity within the deprived visual system is a third use of monocular occlusion in therapeutic ophthalmology, viz., treatment of amblyopia. Amblyopia is a condition of diminished visual form sense without any abnormalities or dysfunction in the organic structure of the visual system. Treatment for this condition usually consists of occluding, in an alternating manner, "the fixing and non-fixing eye for a minimum of 6 weeks" (Costenbader, 1966). After this time period the condition of amblyopia ordinarily disappears, provided that the patient is treated early in life, since with advancing age there seems to be a decreasing success-rate for this form of treatment. (It is important to note that this alternate patching of the eyes is not essential for the treatment of amblyopia. However, the success-rate is increased.)

Although these clinical observations indicate that eye-patching of one eye can exert a beneficial effect on the other eye, they have not demonstrated the existence of an improvement in visual sensitivity. Nevertheless, the evidence does suggest that such a phenomenon might occur, particularly if the occlusion of the eye should be for a prolonged period of time. In view of these observations, together with the lack of experimental data on the sensitivity of the deprived visual modality, it was felt that an experiment should be conducted to determine whether an improvement in visual sensitivity, as measured by the CFF, can occur in the non-occluded eye after a one-week period of monocular deprivation.

CHAPTER III

EXPERIMENTAL METHOD AND RESULTS

EXPERIMENT I

The purpose of the first experiment was to determine the changes in the CFF of both the occluded and non-occluded eye after one week of monocular deprivation of the dominant eye.

Method

Subjects

Twenty-eight male university students were subdivided into an experimental and control group, each containing 14 subjects. All subjects received financial remuneration for their participation in the experiment.

The experimental subjects were required to live, in groups of two, in a large, windowless room (3.66 x 14.02 m) for a period of one week. It was furnished with wall-to-wall carpeting, comfortable chairs, study desks, and contained such facilities as a radio, television set, playing cards, a chess set, and reading material. A washroom, a kitchenette, and sleeping quarters were located adjacent to this furnished room. The subjects were free to move around their living quarters and to engage in activities of their own choice (for detailed instructions, time schedule, etc., see Appendix A). The only restrictions imposed upon them were meals on a fixed schedule, 8 hours of sleeping time, and an inability to leave their quarters e.g., to go to classes.

During the entire experimental period, the subjects wore a black patch over the dominant eye. (Eye dominance was determined by a finger-pointing test.) Periodic checks were made to ensure that there were no light leaks. As a further precaution, the lights were put out in the washroom during its use. At least one experimenter was on duty at all times.

Test Procedure

A 15-minute period of binocular dark adaptation was imposed on both groups of subjects prior to the pre-test CFF determinations. Similarly, on the post-test, a week later, the controls were dark adapted for 15 minutes binocularly and the experimentals monocularly (the non-occluded eye), to ensure that both eyes would be adequately dark adapted. All measurements were taken between 8:45 a.m. and 9:30 a.m., with each subject's testing time not varying by more than 5 minutes over the two test periods.

The stimulus consisted of a white light, at an initial flicker frequency well above fusion (approximately 60 $\pm$ 5 cps), which was presented monocularly by means of a cold cathode modulating lamp (Sylvania, Type R1131c, crater diameter = 0.236 mm). The position of the stimulus was such that it subtended a visual angle of $2^{o}10'$, thus assuring full foveal stimulation. The flicker generating apparatus (Grason-Stadler, Model E622) was set at a light-dark ratio of 0.50 and the current regulator at 22.6 mA. The descending method of limits was used, the flicker frequency being reduced in steps of 1 cps by means of a continuous variable control.

The subject's task was to report the first indication of flicker. Eight trials, separated by a 5-second inter-trial interval, were presented to each eye through a viewing chamber (Lafayette, model 1202C). The arithmetic mean of these eight trials was taken as the descending CFF threshold for each subject.

The control subjects were tested at the same time intervals and at the same time of the day as the experimentals. However, they were not confined to the laboratory during the one-week interval. Both groups of subjects were run concurrently.

In order to familiarize the two groups of subjects with the test procedure, a practice session was provided one day prior to the experiment. Furthermore, the same standard set of instructions (see Appendix A) was read to the subjects prior to the practice session and at the two subsequent test sessions.

Results

Table I presents a summary of the results. A series of t-tests for correlated measures revealed no significant pre-post differences in the mean CFF of either eye of the control group or of the occluded eye of the experimental group. However, the non-occluded eye (non-dominant eye) showed a mean improvement of 2.47 cps ($p < .001$) after the one-week period of monocular deprivation. Furthermore, a difference of differences t-test analysis revealed that this improvement in CFF was also statistically significant relative to both the performance of the occluded eye and of the non-dominant eye of the controls

(p's $< .001$).

An examination of the individual performances of the 14 experimentals indicated that all subjects showed an improvement in the non-occluded eye, with the gains ranging from 0.87 to 5.62 cps.

TABLE I

Mean Changes in CFF in Two Groups of Subjects: Experiment I

	Experimental Group		Control Group	
Test Period	Occluded Eye (Dominant)	Non-Occluded Eye (Non-Dominant)	Dominant Eye	Non-Dominant Eye
Pre	41.35	40.16	42.02	40.74
Post	41.15	42.63	41.99	40.50
Difference	-0.20	+2.47*	-0.03	-0.24

*$p < .001$.

EXPERIMENT II

The purpose of the second experiment was to determine whether a significant improvement in the resolving power of the non-occluded eye will also occur if the non-dominant or weaker eye is occluded for a one-week period. Furthermore, since the same procedure is being employed, this study will also serve as a replication of the first.

Method

Twenty male university students were subdivided into two groups of 10 subjects each. The procedure was identical to that of Experiment I except for the occlusion of the non-dominant rather than the dominant eye.

Results

Table II presents a summary of the results. Again, it can be seen that neither the two eyes of the control group or the occluded eye of the experimental group showed a significant pre-post difference in performance. A mean improvement of 1.84 cps, however, was observed in the non-occluded eye (dominant) of the experimental subjects ($p < .01$), an improvement which was again significant relative to the performance of the occluded eye or of the dominant eye of the controls (p's $< .001$).

TABLE II

Mean Changes in CFF in Two Groups of Subjects: Experiment II

	Experimental Group		Control Group	
Test Period	Occluded Eye (Non-Dominant)	Non-Occluded Eye (Dominant)	Non-Dominant Eye	Dominant Eye
Pre	41.41	42.34	40.57	41.65
Post	41.01	44.18	40.34	41.61
Difference	-0.40	+1.84*	-0.23	-0.04

*$p < .01$

An examination of the individual performances of the 10 experimental subjects revealed that all except one (who remained at the pretest level) showed an improvement in the non-occluded eye, with gains ranging from 0.87 to 4.50 cps.

A comparison of the results of these two experiments appears to suggest that the facilitatory effect occurring in the weaker, non-occluded eye is somewhat greater than the effect occurring in the dominant eye (gain of 2.47 cps or 6.10 percent vs. a gain of 1.84 cps or 4.35 percent, respectively). This result is probably related to the initial differences in the CFF of the two eyes. Since, under normal conditions, the weaker eye almost invariably shows a lower CFF than the dominant eye (approximately 1 to 1½ cps), the likelihood of showing a greater improvement is considerably enhanced.

EXPERIMENT III

Since a significant increase in the CFF of the non-occluded eye has been demonstrated, a third experiment was conducted whose purpose was to determine the temporal course of development of this phenomenon during one week of monocular deprivation of the dominant eye.

Method

Sixteen experimental subjects and 16 controls, drawn from the same population as the preceding two studies, were tested at intervals of 0, 1/3, 1, 2, 3, 5, and 7 days. The measures were always taken between 8:45 a.m. and 9:30 a.m. except at the 8-hr. period when they were given late in the afternoon (4:45-5:30 p.m.). Since it has been demonstrated that the performance of the occluded eye is not affected, the CFF determinations in the experimental group were restricted to the non-occluded eye (non-dominant). These results were then compared with those derived from the non-dominant eye of the controls. A 15-minute period of dark adaptation preceded the measurements taken at the seven temporal periods. Apart from the use of interpolated test sessions, the procedure was identical to that employed in Experiment I.

Results

Figure 1 summarizes the results of Experiment III. It can be seen that the experimental subjects, relative to the controls, show a progressive increase in CFF, of a negatively accelerated nature, as a function of duration of monocular deprivation. An analysis of variance (mixed design for repeated measures, Myers, 1966) performed on this data revealed a significant difference between the two groups ($F = 56.99$; $p < .001$), a significant change over days ($F = 54.66$; $p < .001$), and a significant interaction effect ($F = 44.14$; $p < .001$). The statistical results are summarized in Table III.

TABLE III

Summary of Analysis of Variance, Mixed Design

Source	df	Mean Square	F	p
TOTAL	223			
Between-S	31			
A	1	98.863	56.99	<.001
A/S	30	1.750		
Within-S	192			
B	6	8.144	54.66	< .001
AB	6	6.577	44.14	< .001
SB/A	180	0.149		

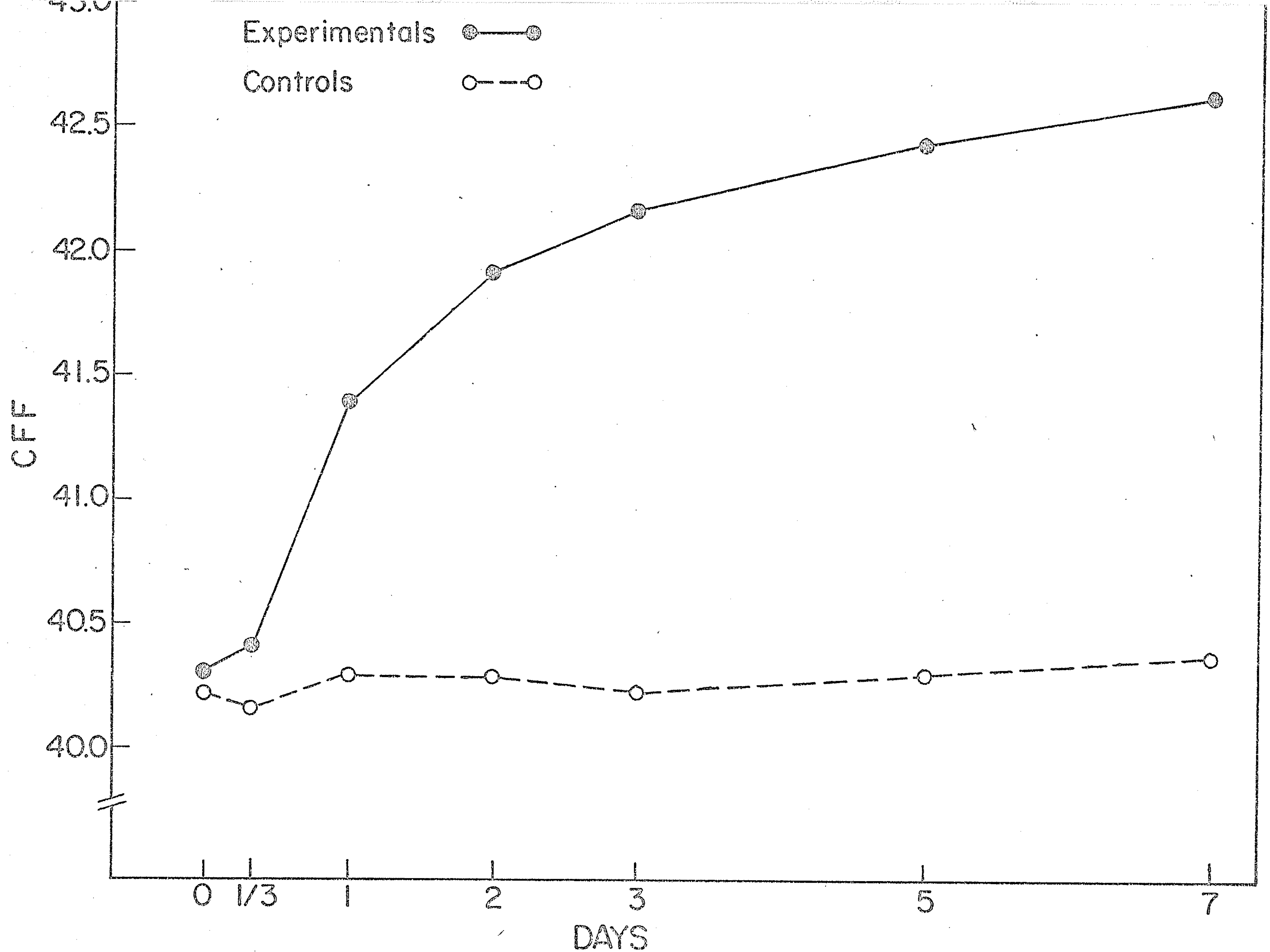
Experimentals
Controls
CFF
42.5
42.0
41.5
41.0
40.5
40.0
0
1/3
1
2
3
5
7
DAYS

Fig. 1.

Since the interaction effect was significant, a series of individual two-tailed t-tests, for independent groups, were performed comparing the performance of the two groups of subjects at the various temporal periods. This analysis revealed a significant difference at all durations ($p's < .001$) except at 0 and 8 hours.

All 16 experimental subjects showed an improvement in the CFF at the end of the one-week period, the individual gains ranging from 0.62 to 4.12 cps (mean = 2.34).

Finally, in an attempt to determine the approximate duration of the after-effects, three experimental subjects who showed a considerable improvement in CFF (one from each of the three experiments), were tested at follow-up intervals of 3 and 7 days <u>after</u> the removal of the eye patch. Their mean CFF values at 0 and 7 days of monocular deprivation, and on post-occlusion days 3 and 7, were 38.21, 42.75, 41.12, and 38.92, respectively, (see Fig. 2). The results of this exploratory study, therefore, suggest that a sizeable after-effect is still present one week after the removal of the eye patch.

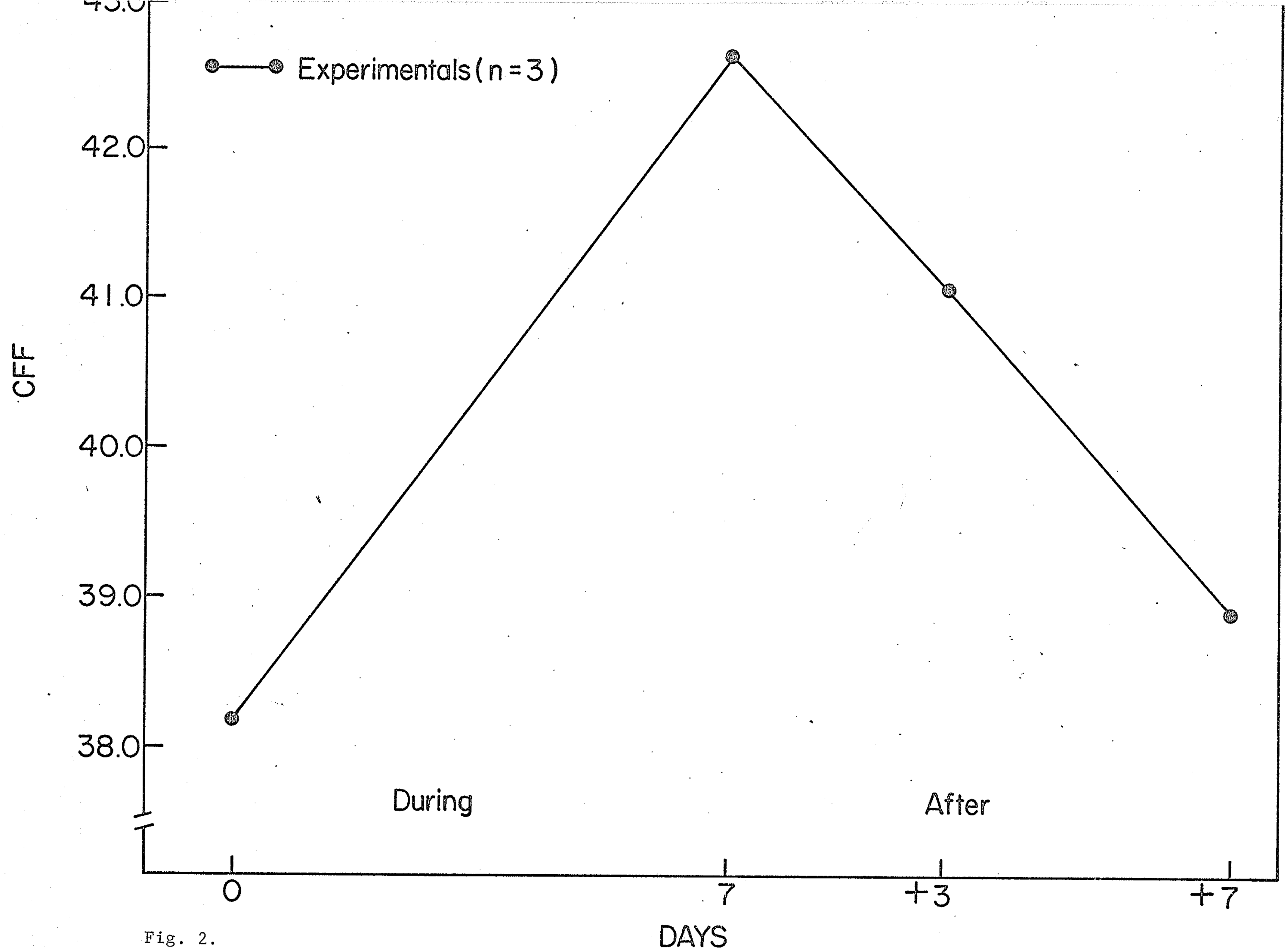
Experimentals (n = 3)
CFF
42.0
41.0
40.0
39.0
38.0
During
After
0
7
+3
+7
DAYS

Fig. 2.

CHAPTER IV

DISCUSSION

The results of the first two experiments have shown that there is no significant change in the CFF of the occluded eye after a week of monocular deprivation. These negative results are consistent with those reported by Duda (1965) after a week of binocular deprivation (darkness). Further confirmation of these results has been reported in two PD experiments in which both eyes were exposed to unpatterned homogeneous stimulation. Doane et al. (1959) found no significant changes in the CFF after a 3-day period and Zubek (1964) after a 14-day period. Thus, regardless of whether the prolonged occlusion involves constant darkness or unpatterned light, no significant changes in the CFF appear to be present in the visually deprived eye(s).

In contrast to this negative finding, the results of all three experiments have conclusively demonstrated a significant improvement in the CFF of the non-occluded eye, an effect which occurred regardless of whether the dominant or non-dominant eye was visually deprived. Furthermore, this phenomenon was quite pronounced with all 40 experimental subjects, except one, showing an improvement, with the individual gains ranging from 0.62 to 5.62 cps. (The mean gain, over the three experiments, was 2.21 cps). In addition, some evidence was obtained which suggested that this facilitatory effect was still present, to a noticeable degree, one week <u>after</u> the removal of the eye patch. The existence of such a striking and long-lasting improvement in the non-isolated eye indicates an inter-ocular transfer effect of visual deprivation, and hence, the involvement of some central regulating mechanism in the higher levels of the visual system.

One of the most important findings (Experiment III) was the presence of a negatively accelerating improvement in CFF as a function of duration of visual deprivation. It is interesting to note that a similar functional relationship has been obtained in two recent inter-sensory experiments conducted at the Manitoba laboratory (Milstein & Zubek, in press; Pangman, 1970). Using measures of tactual fusion frequency and auditory flutter fusion frequency, tasks analogous to the CFF, a progressive improvement in performance with time was observed during a week of visual deprivation (darkness). Thus it would appear that when sensory measures, involving intermittent stimulation, are employed, the same temporal pattern of improvement in sensitivity will occur regardless of whether the determinations are taken within a sense modality or across modalities. A further similarity pertains to the duration of the after-effects. In both the present experiment and in two earlier inter-sensory studies, employing measures of auditory and tactual fusion (Duda & Zubek, 1965; Zubek, Flye, & Aftanas, 1964), the facilitatory effects persisted for a number of days following the termination of visual deprivation. Whether the same pattern of results, within and across modalities, would occur if non-"flicker" sensory measures were to be employed, remains to be determined.

The results of Experiment III indicated the presence of an increase in the CFF at the first test period--8 hours of monocular deprivation (see Fig. 1). Although this effect was not statistically significant, the presence of a trend toward improvement is important in the light of some surprising CFF results reported by Allen in 1923. After placing a black eye patch over the left eye for approximately 3 hours, Allen measured the CFF of the right eye for 15 different spectral colours, ranging from 410 mu to 750 mu, and then compared these results with those derived from the same subject when his left eye was not occluded. The results revealed a decrease in the CFF of the non-occluded eye, relative to the control condition, for all 15 test stimuli. This finding was subsequently confirmed by Allen's assistant, Hollenberg (1924). Although only one subject was employed in both studies, the amazing consistency of the results over a wide spectral band suggests that a genuine depression effect may have been demonstrated. In some further research, Allen (1923) also reported that the maximum effect "is not obtained by blind-folding the eye or by keeping it in complete darkness, as would quite naturally be expected, but by exposing the eye to light of very low intensity, such as that in a dimly lighted dark room" (p. 609).

These results reported by Allen and Hollenberg, in conjunction with those obtained in this study, appear to suggest that monocular deprivation may initially produce a depression ofthe CFF in the non-occluded eye followed subsequently by an enhancement effect. In order to test this hypothesis, the writer is now conducting a study in which CFF determinations in the non-occluded eye are being taken at intervals of 0, 3, 6, 9, 15, and 24 hours of monocular deprivation. Although only three experimental subjects have been tested so far, some strong support for this hypothesis is already available. All three subjects have shown an initial depression of the CFF, with the maximum occurring at 6 hours, a reversal to the pre-experimental level at 9 hours, and a subsequent enhancement effect which, at the 24-hour period, was approximately 1.25 cps above the baseline value. (The presence of an enhancement effect at 1 day is consistent with the results of Experiment III.) No evidence of any temporal changes in the CFF was present in three control subjects who were tested concurrently.[2] These controls, incidentally, were confined for the entire 24-hour period in the same large room as the experimentals, thus ensuring the same environmental condition for both groups of subjects. (No temporary shifts in eye-dominance of the experimental subjects were evident at the end of the day. Unfortunately, no such observations were made in the present one-week experiments.)

The question now arises as to the possible physiological basis of this unusual visual phenomenon. One possible explanation, particularly of the enhancement phenomenon, pertains to the possibility that the eyes exert a mutual inhibitory effect such that the occlusion of one eye removes its inhibitory influence on the other eye. That such a mechanism may be present is suggested by a recent report indicating

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[2] These preliminary findings have now been confirmed in a study employing 15 experimental and 15 control subjects.

that the superior colliculi apparently suppress each other in this way (Sprague, 1966). Although this explanation could account for the increased CFF in the non-occluded eye, one would expect a decrease in the occluded eye. This latter effect, however, did not occur.

A more probable explanation of these results is that monocular deprivation may be producing changes in the central areas of the primary sensory system, changes similar in nature to the denervation supersensitivity which is known to occur in the higher neural centres following partial surgical deafferentation at lower levels of the central nervous systems (Cannon & Rosenblueth, 1949; Stavraky, 1961). The first statement on the general phenomenon of supersensitivity was made over a century ago by Marshall Hall who, in 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" (Stavraky, 1961, p. 3). Since this early observation, numerous investigators have studied various aspects of denervation supersensitivity. For example, Cannon and Rosenblueth (1949) in their monograph on the "Law of Denervation" examined the supersensitivity of muscular tissues when deprived of innervation, and Jaffe and Sharpless (1966) investigated the production of supersensitivity in the nervous system and in the effector organs after the administration of various pharmacological agents.

Stavraky (1961), in a comprehensive review of this topic, has stated that central supersensitivity is brought about through a reorganization of pathways in the central nervous system following partial isolation of sensitive structures, an effect produced either by injury or denervation. This reorganization manifests itself at first by a depression of responsiveness in the isolated region followed subsequently by a supra-normal increase in excitability. One important example of this phenomenon has been reported by Spiegel and Szekely (1955) who observed that lesions in the posteroventral nucleus of the thalamus (relay nucleus for touch) are subsequently followed, after an initial period of depression, by a hyperexcitability of the somesthetic cortex. A similar effect has also been observed in the visual system. Burke and Hayhow (1960) reported a dramatic increase in the lateral geniculate response to repetitive optic nerve stimulation after the visual receptor cells were selectively destroyed by oral administration of a drug. In view of such physiological data, it would appear that our occlusion procedure may be producing a state of temporary partial deafferentation of the visual system resulting in an initial depression in visual sensitivity followed subsequently be an enhancement effect. However, this deafferentation is of a non-surgical nature.

This hypothesis is consistent with Sharpless's (1964) recent formulation of the problem which states that the reported supersensitivity phenomena result from prolonged disuse of neural pathways. "Disuse may be the result of drugs, <u>privation of sensory experience</u>, or, most commonly, injury produced by severance of nervous pathways" (p. 358). Furthermore, he advances the view that supersensitivity is a compensatory process which occurs as a result of "a radical and sustained change in the level of input to an excitable structure" (p. 358).

One of the important questions which our findings raise is whether the temporal pattern of changes in visual sensitivity observed in the non-occluded eye is specific to the CFF measure or whether it represents a more general visual phenomenon. A partial answer to this question has recently been provided in an unpublished doctoral dissertation. In this study, in which six visual measures were administered tachistoscopically at intervals of 0, 6, 12, 24, and 48 hours of monocular deprivation (darkness), Dusansky (1968)[3] reported a significant improvement in visual acuity (broken circles) and perception of curvature in both the occluded and non-occluded eyes. Furthermore, this effect was present at all test durations and to the same degree. No significant changes were observed on measures of brightness sensitivity, color saturation, numerical recognition, and recognition of geometric patterns. Since no evidence for an initial depression in performance followed by an enhancement effect of a negatively accelerating nature was provided in this study, it would appear that our phenomenon is specific to the use of a measure involving intermittent stimulation. This, however, may not be the case. First, Dusansky employed a lengthy battery of tests. Second, the visual measures were presented separately to the right and left fields of the test eye. It is conceivable, therefore, that if our procedure had been utilized, i.e., foveal vision and only one measure (e.g., visual acuity), the obtained results may have agreed more closely with

[3] Unfortunately, the writer did not become aware of this Ph.D. dissertation until the completion of this series of experiments.

those reported in this study.

It is evident from the results of these two eye-occlusion experiments that the answer to the problem of the functional status of the deprived visual modality is a complex one, an answer which seems to be dependent upon such variables as the degree of complexity of the visual tasks, their stimulus characteristics, locus of retinal stimulation, use of isolated or non-isolated eye, and duration of deprivation. In addition, the type of deprivation, whether darkness or unpatterned light, may be an important variable. Although the problem is a difficult one, a notable beginning toward its solution appears to have been made.

In conclusion, it would appear that the monocular deprivation technique may provide a new method of attacking the complex problem of the neural mechanisms underlying sensory isolation effects, an approach which can be used both in human behavioral studies and in electrophysiological investigations employing animals.

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APPENDIX A - TEST INSTRUCTIONS

Phone Call to Experimental Subjects to Arrange for Participation

This is (name of caller) from the Department of Psychology at the University of Manitoba. We are calling about the one-week experiment you volunteered to participate in. We would like you to begin your participation on (date and time). At this time you and another student will begin living together for one week under a condition of monocular deprivation. No restrictions will be placed on talking or moving about the room and a radio, TV set, and reading material will be available at all times. You will receive $100.00 for your participation. Since we will want to give you certain behavioral tests prior to your participation, it is necessary that you come into the laboratory for approximately half an hour on (date and time). Please come to Room 513, Duff Roblin Building.

It is important that you take no medication of any kind e.g., analgesics, from now until the end of the experiment.

Phone Call to Control Subjects to Arrange for Participation

This is (name of caller) calling from the Department of Psychology, at the University of Manitoba. We are calling about the experiment you volunteered to participate in. For this experiment you will be required to come to our laboratory several times over an 8-day period. Each session will take ½ hour or less. For your assistance you will receive $20.00.

We would like you to come on (date and time). At that time you will receive a schedule as to when you are to be at the laboratory. Please come to Room 513, Duff Roblin Building.

It is important that you take no medication of any kind e.g., analgesics, from now until the end of the experiment.

Instructions Read to Experimental Subjects on Arrival for Practice Session

This is an experiment on the effect of living under a condition of monocular deprivation. There is no danger involved. You will be at liberty to engage in the activities lined out in the regulations. During the course of the week you will periodically receive behavioral tests identical to those you are about to receive today.

Tomorrow when you report to the laboratory you are to bring a blanket, pillow, tooth brush, tooth paste, and change of clothes. However, it is not necessary to bring a razor as you will not be able to use it. If you smoke, bring enough cigarettes for the entire week as you will be allowed to smoke after each meal and at your coffee break (but not at other times). A well-balanced diet is provided but you may wish to order in food; therefore, it is advisable to bring a small amount of money.

It is important that you take no medication of any kind e.g., analgesics, from now until the end of the experiment.

Do you have any questions?

Laboratory Regulations for Experimental Subjects

Time Table:

8:00 A.M.	Wake Up
8:15 A.M.	Breakfast
10:30 A.M.	Coffee Break
12:30 P.M.	Lunch
3:30 P.M.	Coffee Break
6:30 P.M.	Supper
10:30 P.M.	Coffee Break
11:00 P.M.	Bed Time (11:20 maximum limit - after National News)

Regulations:

- Smoking allowed only immediately after meals and coffee breaks (Maximum - two cigarettes)
- Only factory sealed cigarettes or tobacco will be allowed into the lab.
- Cigarettes will be doled out by the experimenter on duty.
- Masks shall NOT be removed or loosened under any circumstances. Experimenter on duty will make any necessary adjustments. You must report any light leakage at once. A spot check will be conducted to insure that the masks are properly worn. (Subjects will be dismissed without any financial reimbursement if this condition is violated.
- Subjects must not leave the lab area without first notifying the experimenter.
- Lights in the bathroom must be TURNED OFF when occupied.
- Lab must be kept clean at all times. Furniture must be replaced at bed time.
- Noise level must be kept at a minimum (Radio, TV, etc.).
- No musical instruments will be permitted.
- No visitors will be allowed.

- Subjects must be appropriately dressed at all times.
- No phone calls will be permitted.
- No deliveries of parcels, books, notes, messages, etc., from friends and acquaintances will be accepted.
- Two hot evening meals will be served. (Food may be ordered in at subject's expense - e.g., Pizza, etc.).

Subject Participation Agreement

I, the undersigned, hereby agree to abide by all the regulations of this one-week experiment on monocular deprivation. Furthermore, I promise not to remove, under any circumstances, the experimental eye patch and mask, to confine my movements to the prescribed laboratory area, and to follow all instructions pertaining to the experiment and tests, given to me, by the laboratory personnel. I understand that a violation of any of the above conditions, even on one occasion, provides grounds for dismissal from the experiment without any financial reimbursement for my participation in it. If for any reason I have to withdraw voluntarily from the experiment, before the termination of the prescribed period of seven days, I promise to submit to the standard tests associated with this experiment in order to receive partial payment for my participation.

Signature ______________________________

Date ______________________________

Instructions Read to Control Subjects on Arrival

For Practise Session

In this experiment we are interested in determining the resolving power of your eye over an eight day period. Here is your test schedule. It is important that you be here exactly at the time indicated on the schedule. If you are late, you may be dismissed from the experiment with no payment.

Are there any questions?

Control Subjects Participation Agreement

I promise that I will abide by all the regulations that I have been given. Furthermore, I promise that I will not talk about or describe to anyone, any of the tests which may be administered to me during the course of the experiment. If I violate any of the instructions, I will forfeit all payment for services rendered.

Signature ____________________________

Date ________________________________

Instructions for the CFF

The purpose of this test is to determine the resolving power or sensitivity of your eye. Place your head firmly against the viewer in front of you, putting your elbows on the table and press slightly with your hands against the sides of the viewer, but do not exert too much pressure since this might distort the viewing frame. When I say "ready", a light will appear in the viewer at a flickering frequency too high for the human eye to distinguish. The frequency will then be gradually decreased until at some point you will no longer see the light as a steady spot and it will start to flicker. Indicate by saying "now" as soon as you first see the flicker appearing.

Are there any questions?

Remember, this is a difficult task, so concentrate hard on what you are doing and follow the instructions exactly. Eight trials will be given to each eye, starting with your __________eye.

APPENDIX B - RAW DATA

EXPERIMENT I

Experimental Group: Mean CFF Scores

	Dominant (Occluded) Eye		Non-Dominant Eye	
Subject	Pre	Post	Pre	Post
E- 1	43.750	41.250	41.250	42.875
E- 2	32.500	39.750	32.000	37.625
E- 3	40.875	38.875	41.500	42.375
E- 4	42.625	41.625	41.250	42.375
E- 5	42.125	42.000	41.250	45.750
E- 6	40.500	40.125	38.125	39.875
E- 7	42.875	42.875	42.625	46.875
E- 8	40.625	40.750	40.250	41.875
E- 9	43.125	41.875	43.375	46.500
E-10	40.125	40.250	39.375	40.250
E-11	45.375	42.625	41.500	44.875
E-12	43.125	43.750	42.125	43.125
E-13	41.125	39.125	38.750	40.750
E-14	40.500	41.250	38.875	41.750

EXPERIMENT I

Control Group: Mean CFF Scores

	Dominant Eye		Non-Dominant Eye	
Subject	Pre	Post	Pre	Post
C- 1	40.875	41.250	40.375	40.375
C- 2	43.000	42.875	42.250	41.875
C- 3	40.250	39.750	39.125	39.125
C- 4	42.500	42.125	41.875	41.125
C- 5	40.625	40.125	37.875	37.125
C- 6	43.750	44.625	41.625	41.750
C- 7	41.750	41.500	40.375	40.250
C- 8	40.375	40.375	41.250	40.750
C- 9	41.000	41.000	39.875	39.500
C-10	42.375	42.500	41.125	40.500
C-11	42.375	41.625	41.500	40.500
C-12	41.750	42.500	40.625	41.125
C-13	42.875	43.625	39.750	41.000
C-14	44.750	44.000	42.750	42.000

EXPERIMENT II

Experimental Group: Mean CFF Scores

	Dominant Eye		Non-Dominant (Occluded) Eye	
Subject	Pre	Post	Pre	Post
E- 1	43.875	47.875	43.125	42.125
E- 2	45.000	49.500	43.500	44.250
E- 3	43.375	44.375	44.375	42.125
E- 4	41.000	42.750	42.125	42.500
E- 5	45.250	46.125	41.000	40.875
E -6	39.125	41.125	38.625	40.375
E- 7	40.750	43.250	39.750	38.750
E- 8	38.125	38.125	37.000	34.750
E- 9	45.125	46.000	40.375	41.625
E-10	41.750	42.625	44.250	42.750

EXPERIMENT II

Control Group: Mean CFF Scores

	Dominant Eye		Non-Dominant Eye	
Subject	Pre	Post	Pre	Post
C- 1	40.875	41.250	40.375	40.375
C- 2	43.000	42.750	40.250	41.875
C- 3	40.250	39.750	39.125	39.125
C- 4	42.500	42.125	41.875	41.125
C- 5	40.625	40.125	37.875	37.125
C- 6	43.750	44.625	41.625	41.750
C- 7	41.750	41.500	40.375	40.250
C- 8	40.375	40.375	41.250	40.750
C- 9	41.000	41.625	39.875	39.500
C-10	42.375	42.500	41.125	40.500

EXPERIMENT III

Experimental Group: Mean CFF Scores (Non-Dominant, Non-Occluded Eye) at Seven Temporal Periods

Subject	Day 0	8 Hrs.	Day 1	Day 2	Day 3	Day 5	Day 7
E- 1	41.250	41.000	42.375	43.125	43.625	44.375	44.375
E- 2	40.125	41.000	42.750	43.000	43.000	43.250	43.375
E- 3	40.625	40.625	41.625	42.125	43.000	42.500	43.000
E- 4	41.000	41.125	42.000	42.375	42.625	42.500	42.875
E- 5	39.375	40.500	41.875	42.625	42.625	43.500	43.500
E- 6	40.500	39.625	41.125	41.875	42.250	41.875	42.250
E- 7	39.750	40.250	41.250	40.000	40.250	40.250	40.375
E- 8	40.875	40.375	41.625	41.875	42.250	43.375	42.750
E- 9	41.125	40.750	41.375	42.000	41.875	42.250	42.375
E-10	40.375	40.250	41.250	41.500	43.375	43.875	43.875
E-11	39.500	38.875	40.500	41.375	41.250	41.250	41.500
E-12	40.000	40.625	41.125	41.375	41.625	41.750	41.625
E-13	38.125	41.000	40.500	41.125	42.000	42.125	42.250
E-14	41.375	40.875	41.625	41.875	42.625	42.500	42.500
E-15	39.750	38.500	40.125	41.250	40.625	41.000	41.000
E-16	40.875	40.375	41.250	42.250	41.875	44.000	44.375

EXPERIMENT III

Control Group: Mean CFF Scores (Non-Dominant Eye)

at Seven Temporal Periods

Subject	Day 0	8 Hrs.	Day 1	Day 2	Day 3	Day 5	Day 7
C- 1	40.875	40.625	41.125	42.250	40.250	40.875	41.125
C- 2	41.250	40.625	40.875	40.625	40.625	40.875	40.500
C- 3	38.750	38.875	39.125	38.125	38.625	39.125	39.000
C- 4	40.750	40.250	41.000	41.250	41.125	40.875	41.000
C- 5	41.500	41.375	41.375	41.500	41.500	41.875	41.750
C- 6	39.125	38.875	39.000	39.125	39.625	39.250	39.250
C- 7	41.250	41.125	41.125	40.875	41.125	41.250	41.250
C- 8	40.500	40.750	40.625	40.750	40.875	40.500	40.625
C- 9	39.375	39.625	39.750	39.875	39.375	39.875	39.500
C-10	42.000	41.250	41.625	41.875	41.625	41.875	41.875
C-11	39.375	39.500	39.375	39.750	39.375	39.000	39.000
C-12	38.625	38.625	38.625	38.750	38.625	39.000	38.875
C-13	39.625	39.375	39.500	39.625	39.500	39.500	39.375
C-14	40.250	40.500	41.000	40.625	40.625	40.500	40.750
C-15	40.000	40.875	40.750	40.625	40.750	40.500	41.000
C-16	40.250	40.375	40.000	40.250	40.125	39.625	41.000