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**LA THÈSE A ÉTÉ
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**Contrast Sensitivity as a Function of
24 Hours of Monocular Occlusion**

Mary J. Harsh

A Thesis

in

The Department

of

Psychology

**Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Arts at
Concordia University
Montréal, Québec, Canada**

December 1985

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ABSTRACT

Contrast Sensitivity as a Function of
24 Hours of Monocular Occlusion

Mary J. Harsh

The effect of monocular occlusion on the contrast sensitivity function (CSF) was examined in an attempt to assess the interocular depression-enhancement effect. In Experiment 1, the experimental subjects were confined to the laboratory for a 24-hour period with one eye occluded. The CSF of the non-occluded eye was determined at intervals of 0, 3, 6, 9, 12, and 24 hours. No significant difference was found in the CSF between the experimental and control groups (N=4 per group). A trend towards an increase from the baseline CSF over 24 hours for both the experimental and the control subjects was observed, indicating a potential practice effect. Experiment 2 utilized an automated contrast sensitivity test to assess if this increase in sensitivity was specific to the contrast sensitivity charts used in Experiment 1, or due to practice effects. Twenty-four female university students divided into experimental and control groups were run following the same procedures in Experiment 1. As in Experiment 1, the original hypothesis that experimental subjects undergoing 24 hours of monocular occlusion would demonstrate the depression-enhancement effect in contrast sensitivity, whereas control subjects would show no such change was not supported. A significant practice effect in sensitivity to sine-wave gratings was seen, $F(5, 110) = 3.63$, $p < .01$. The results were discussed in reference to spatial and temporal mechanisms in vision. Further studies using temporal measures of contrast sensitivity were recommended.

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Introduction

The study of sensory processes investigates the role of our sensory modalities in our perception of the world. One set of questions which this area addresses concerns the factors which can affect the nature of our sensory sensitivity within a given modality and the possible interactions that can occur between sensory modalities.

Experimental sensory restriction has been used for several decades to investigate inter- and intramodal sensory effects. This research has provided information on many psychophysical, psychological, and electrophysiological changes which occur during sensory restriction, and has been used to assess the viability of various theoretical models of sensory threshold regulation.

Interest in the effects of reduced sensory input has stemmed from attempts to understand such phenomena as arousal mechanisms, monotonous stimulation, brainwashing, and permanent sensory deprivation (e.g. blindness and deafness). Reduced sensory input has been achieved by two methods of restriction: sensory deprivation (SD) and perceptual deprivation (PD). SD attempts to minimize or eliminate all sensory input to a given modality, whereas the objective of PD is to eliminate meaningful stimulation but not the level of stimulation. SD is achieved through the use of sound-proof and/or light proof rooms, binocular masks, ear plugs, restriction of body movement or tactual sensation, etc. On the other hand, PD is accomplished by utilization of a constant masking sound (white noise) or by the use of a translucent but not transparent eye patch or mask. In addition to using subjects with normal sensory abilities, subjects with permanent sensory restrictions,

including amputees, the visually impaired (e.g. amblyopic, anisometropic, or blind), and hearing impaired individuals have provided data in the attempt to understand the effects of reduced sensory input.

Theoretical Background

Theoretical models advanced to account for sensory changes and interactions as a function of sensory restriction have focused primarily on the neural and cortical correlates of sensory processes. Neurologically-based theories of threshold regulation are based on observations and neuroanatomical determinations between the sensory modalities, and between parts of those modalities. Lindsley (1961) advanced the first theoretical model of this type by focusing upon the ascending reticular activating system (ARAS) of the brain stem and the thalamocortical projection system to postulate a homeostatic theory of sensory threshold regulation. Lindsley describes these two systems as a homeostat that regulates sensory sensitivity in a hypothesized optimal range. The ARAS monitors and regulates all sensory activity processed in the central nervous system. The theory argues that one of the primary functions of the ARAS is to ensure that adequate levels of sensory input are maintained in order to have enough reticular activity available to activate higher cortical levels. One specific prediction of this theory is that reduced levels of sensory input will signal the reticular formation to bring about a lowering of sensory thresholds.

A more advanced theory which stresses a homeostatic mechanism of sensory sensitivity named "Sensoristasis" was postulated by Schultz (1965). Sensoristasis is defined as a drive state of cortical arousal which impels the organism to maintain an optimal level of sensory

variation. When stimulus variation is restricted, as in visual or auditory deprivation, central regulation of threshold sensitivities will function to lower sensory thresholds. In an attempt to restore the balance, the organism becomes increasingly sensitized to stimulation. Zuckerman (1969) makes a similar prediction in the Optimal Level of Stimulation Theory. He states that the areas of the central nervous system which mediate the sensory modalities will respond with increased sensitization and excitability when a sensory modality is isolated.

Blindness Research

These theoretical models are of clinical importance to individuals with sensory impairments. There is a long-standing controversy over the existence of sensory compensation in the nondeprived sensory channels of the deaf and blind. For example, blind individuals are often able to avoid running into obstacles. Several theories that attempt to account for this phenomenon suggest the existence of enhanced sensory abilities in the blind. One theory holds that the touch and temperature senses have developed compensatory functions in the blind to enable them to feel air currents as they are affected by the proximity of obstacles. An alternative theory argues that auditory cues in the form of echoes from objects provide the explanation for the perception of obstacles by the blind.

A series of experiments in the 1940's attempted to choose between these two explanations. In the first of these experiments, Supra, Cotzin, and Dallenbach (1944) used blindfolded normally sighted subjects and blind subjects to test the effectiveness of auditory cues in obstacle perception. Each subject was instructed to walk down a hallway

and to indicate when he thought he was approaching the obstacle, a wall of fiber board approximately 1.2 by 1.5 meters, and to walk up as close as possible to it without striking it. The results showed that both the experimental and control subjects were able to avoid colliding with the obstacle, and that the blindfolded, normally sighted subjects were able to learn to perceive the obstacles during the experimental trials.

When sound cues were reduced by having the subjects walk in their stocking feet over thick carpeting or by plugging their ears, obstacle avoidance was poor or eliminated. In most cases, this result occurred even though the head, arms, and hands were open to potential stimulation. This indicated that touch is not sufficient for the perception of obstacles at a distance. In a second experiment, which supported these findings, all sensory channels of stimulation except audition were eliminated by placing subjects in a sound-proof room. The subjects were instructed to judge the experimenter's approach to the obstacle by the sounds of the experimenter's footsteps which were picked up by a microphone and transmitted to the subject through an amplifying system and earphones. Under these conditions, all subjects were able to perceive the experimenter's approach to the obstacle and this ability was only slightly inferior to when they themselves walked toward the obstacle.

Research with deaf-blind subjects has also added support to the theory that auditory stimulation is both a necessary and sufficient condition for obstacle perception of the blind. Worchel and Dallenbach (1947) demonstrated that deaf-blind subjects did not initially avoid obstacles, nor were they capable of learning to perceive obstacles

during the testing period. They concluded that the cutaneous surfaces of the external ears (meatuses and tympanums) are not sufficient for the perception of obstacles, and that audition is involved in the perception of obstacles of the blind.

These studies have identified the avoidance mechanism in the blind but have not demonstrated a superiority of this ability in the blind. Kellogg (1962) provides support to a blind subject's superior spatial abilities using sounds when compared to blindfolded normally sighted control subjects. One task required subjects to indicate whether a 30.5 cm (1 foot) wood disk that was moved silently by the experimenter to one of seven fixed positions was nearer or farther away than a disk held at a constant distance of 61 cm (2 feet). Other tasks required a comparison of disks of different sizes to a standard-sized disk, and a comparison of disks of different textures (sheet metal, glass, plain and painted wood, denim, and velvet). In general, blind subjects were able to derive distance, size, and texture information from the echoes from the stimuli whereas the performance of the blindfolded normally sighted subjects was at about a chance level. Also, the control subjects did not learn object avoidance over 100 trials of each task. The author's conclusion is that the perception of echoes reflected from objects provides sufficient information for object detection and avoidance in the blind, and that this ability is superior in blind subjects when compared with temporarily visually restricted control subjects.

Research on the effects of restricted sensory input has interesting implications for therapeutic procedures that use monocular occlusion as part of the treatment for visual impairments, such as with

amblyopia. Amblyopia, typically characterized by monocular loss of visual acuity without any ophthalmologically detectable cause (Hess, 1981), has been found to respond to occlusion therapy varying from 7-minute periods daily up to continuous occlusion for several months (Schor, Gibson, Hsu, & Mah, 1981). However, several studies conducted on the effect of monocular occlusion itself have shown changes on various visual measures in normally sighted subjects, such as lateral phoria (Bross, 1984) and scotopic sensitivity (Enoch, Birch, & Birch, 1979). As Bross points out, any changes or improvements in visual function in response to monocular occlusion return to baseline values after a period approximately equal to the length of the occlusion period. This raises an important question as to when and for how long assessment of monocular occlusion for therapeutic purposes should occur. Studies with both visually impaired and normally sighted subjects can provide answers to this and many other questions concerning the effects of reduced sensory input.

Experimental Sensory Restriction

The experimental sensory restriction paradigm has most frequently utilized deprived normal vision as it is more difficult to obtain a comparable degree of deprivation in the other senses. Visual deprivation is accomplished with a black cloth mask, in addition to confining the subjects to dark rooms for periods of one to 14 days. Measures of sensory sensitivity are compared with confined and/or non-confined control subjects who are not sensorially restricted.

One of the leading authorities on sensory deprivation was John P. Zubek who conducted the most extensive series of experiments in this

area during 15 years of research at the University of Manitoba. Zubek focused on unimodal deprivation to investigate the sensory systems and their interconnections. In one series of experiments, Zubek and his colleagues investigated the effects of one week of binocular deprivation on tactile, auditory, olfactory, and gustatory sensitivity. Throughout these studies, deprived normal vision was shown to lead to a lowering of thresholds in the nondeprived modalities. Zubek, Flye, and Aftanas (1964) assessed cutaneous sensitivity before and after one week of binocular deprivation. The Critical Frequency of Percussion (CFP), a measure of tactile temporal acuity analogous to Critical Flicker Frequency (CFF) in vision, was determined at the palm, index finger, and forearm. The two-point limen was measured on each palm, and the Hardy-Wolff-Goodall Dolorimeter measured sensitivity to heat and pain at the forearm. All experimental subjects showed increased sensitivity for all measures, whereas no significant changes were shown by the control subjects who were matched with the experimental subjects on baseline values of the measures tested. The aftereffect of the increased sensitivity lasted for 1 day for heat, 2 days for pain, and up to 7 days for tactile acuity.

In another study, Duda and Zubek (1965) demonstrated that 1 week of visual deprivation also lowered thresholds in audition. Improved temporal auditory acuity, as measured by Auditory Flicker Fusion (AFF), was demonstrated in 14 of 15 experimental subjects relative to a control group. However, measures of absolute sensitivity to five tones revealed no differences between experimental and control groups suggesting that modulated types of sensory measures may be more susceptible to

intermodal compensation than non-modulated measures.

In a further experiment (Schutte & Zubek, 1967), olfactory sensitivity was measured by the absolute detection threshold of benzene. The results showed that sensitivity for experimental subjects was significantly improved over control subjects after 1 week of visual deprivation, although the longevity of the improvement was less than previously observed for other measures. In the same study, Schutte and Zubek measured gustatory sensitivity to NaCl, sucrose, quinine, and HCl. The experimental group showed improved sensitivity to salt and sugar, but no significant difference was found for HCl and quinine. An additional study attempted to determine the generality of the compensatory effects by including measures of cutaneous and auditory sensitivity not used previously (Phelps & Zubek, 1969). These included measures of absolute pressure sensitivity of the finger, forearm, neck, leg, and palm. All of these demonstrated significant improvement at all areas except the palm, although, there too was evidence of a strong trend towards improved sensitivity. Additional measures of cutaneous and auditory localization did not show an improvement, a finding which led the authors to suggest that measures of tactual localization, and absolute and differential auditory localization may not accurately assess sensory interaction as these tasks require learning for an improvement in performance to result.

The increasing evidence of compensatory effects of visual deprivation in other modalities suggested that deprivation of other modalities may lead to compensatory visual effects. Bross and Zubek (1975) found an improvement in the Critical Flicker Frequency (CFF) for

their experimental subjects after one week of relative auditory deprivation (silence). Improvements due to auditory deprivation were not confined to a single modality. The Critical Frequency of Percussion (CFP), a measure of cutaneous temporal acuity, also improved during one week of auditory deprivation (Bross & Zubek, 1976).

In addition, it had been shown previously that cutaneous deprivation achieved by isolating the volar surface of the forearm leads to an improvement in temporal tactile acuity measured by CFP (Aftanas & Zubek, 1963). A study which replicated this finding added support to the central mediation of sensitivity changes. Aftanas and Zubek (1964) measured the homologous and nonhomologous areas of the contralateral nonoccluded arm and found an improvement in CFP, although not as large as with the occluded arm, for the homologous area. This transfer of changes in acuity to the contralateral limb points to the operation of central neural mechanisms. Aftanas and Zubek suggested that this transfer phenomenon is probably mediated by somatic area II of the cortex which receives impulses from both sides of the body (Wilson, Wilson, & Swinyard 1962). Although no physiological evidence exists for a monocular homologue in the visual cortex, Aftanas and Zubek suggested that an analogous effect of monocular deprivation on the nonoccluded eye may be observed.

A series of studies investigated the effect of partial and complete visual deprivation on CFF. Bross and Zubek (1972) demonstrated that one week of monocular deprivation of the dominant eye showed a significant increase in CFF for the nonoccluded eye of all experimental subjects. A second study by the same authors demonstrated a similar effect with the

nondominant eye occluded, although the effect was generally not as large as with the dominant eye occluded. In an attempt to determine whether the CFF performance of the nonoccluded eye would continue to improve or whether it would begin to return to the baseline level, due to the subject's adaptation to the novelty of the experiment, the duration of the monocular deprivation of the dominant eye was extended to 14 days (Zubek & Bross, 1973a). The results for the experimental subjects once again showed the typical improvement in CFF of the nonoccluded eye which reached asymptotic levels by day 11. In an attempt to determine whether total darkness or just a lack of patterning to the deprived eye produced the increased sensitivity to the nondeprived eye, Zubek and Bross (1973b) utilized a monocular Ganzfeld rather than a totally darkened occluder. No increased sensitivity of the CFF was observed for either the experimental or control subjects over a three-day period. Therefore, a lack of input as opposed to a lack of patterning appears necessary for the enhanced sensitivity of the CFF during monocular occlusion.

These results were puzzling in view of previous studies which indicated that CFF decreased in sensitivity after three hours of monocular deprivation (Allen, 1923; Hollenberg, 1924). Zubek and Bross (1972) clarified this inconsistency by measuring the CFF of the nonoccluded eye at 1, 3, 6, 9, 15, and 24 hours. The CFF of the nonoccluded eye for the experimental subjects showed a significant decrement at 3 and 6 hours and then an increased CFF, whereas the occluded eye of the experimental subjects or either eye of the confined control subjects showed no changes in CFF, a temporal pattern of changes

referred to as the Depression-Enhancement (D-E) phenomenon. As the original homeostatic models of sensory regulation did not account for the D-E phenomenon, Zubek and Bross suggested another neurological mechanism of sensory regulation, denervation supersensitivity (Sharpless, 1964), to account for the depression component in the CFF of the nonoccluded eye in the early stages of monocular occlusion. This model holds that disuse of neural pathways leads to a depression-enhancement effect in neuronal activity. Sharpless (1964) states that "Disuse may be the result of drugs, privation of sensory experience, or, most commonly, injury produced by severance of nervous pathways" (p. 359). Disuse due to sensory deprivation at first results in an initial depression in sensitivity followed by an enhancement phase representing a compensatory process by which "excitable elements in the nervous system" adjust to too little input (Sharpless, 1964, p. 358). Bross, Harper, and Sicz (1981) have integrated the reticular and denervation based models into a unitary theory of sensory regulation. This theory postulates that the principle of denervation supersensitivity represents the mechanism for setting the levels for sensoristatic activities of the reticular formation. According to this model, reduced sensory input and the accompanying decrease in firing rates at the lower reticular levels will decrease the activation operations of the ARAS. This will result in poorer sensitivity according to reticular theories (Lindsley, 1961). Prolonged disuse of neural pathways (denervation) will result in supersensitivity at the lower brainstem reticular formation, which will be passed on to the ARAS. The resultant increase in ARAS activity will bring about a generalized increase in sensory sensitivity. Bross et al.

hold that this unitary model is able to account for both within and between modality changes in sensory sensitivity.

Similar interocular changes have been noted on other measures of visual function. Tyler and Kaitz (1977) measured the visual evoked potential (VEP) over 9 hours under three conditions: monocular occlusion, anisometropia (unequal stimulation caused by unequal refraction) produced by removing one corrective lens in an observer with +4.50D myopia, and a control condition. They found an increase in amplitude of the VEP for the nondeprived eye for both the monocular occlusion and anisometric conditions. The authors suggest this effect was due to binocular interactions at the level of the lateral geniculate nucleus (LGN) or the visual cortex. The LGN is "arranged in layers of neurons which are excited only by monocular stimulation but which do show binocular inhibition between the monocular layers" (Tyler & Kaitz, 1977, p. 1070). Another possible explanation is that the afferent channel of the nondeprived eye might show increased efficiency in the absence of competitive input from the other eye.

In addition to the use of experimentally deprived vision, researchers interested in the effects of visual deprivation have used subjects who have been functionally monocular most of their lives (e.g. amblyopia, traumatic loss of an eye, monocular congenital cataract). In one such study, Freeman and Bradley (1980) measured vernier acuity, the ability to detect misalignment of edges or bars, for subjects who had been functionally monocularly deprived since childhood, and for subjects who were functionally binocular. They found that functionally monocular subjects demonstrated significantly higher vernier acuities than normal

binocular individuals tested through one eye. The authors suggest that one possible explanation for this increased visual sensitivity is an active neural recruitment as a result of monocular deprivation. Studies of monocular deprivation in animals have demonstrated that preventing normal vision to one eye results in a diminished capacity for stimuli presented through that eye to activate cortical neurons (Olson & Freeman, 1975). This ocular-dominance shift suggests an active process of a cell dominated partially or completely by an eye undergoing reorganization after a lack of input. The cell then becomes responsive primarily or exclusively to the other eye. Therefore, pathways within the cortex which were originally shared by both eyes would now be activated solely through the dominant eye. This suggests that some aspects of visual sensitivity of the non-deprived eye might be relatively high. The visual system's vernier detection capability is extraordinarily fine and thus may represent a behavioural form of neural recruitment. A misalignment of just several seconds of arc can be reliably detected (Berry, 1948), and this represents a fraction of the dimension of a foveal cone (O'Brien, 1951). Therefore, alignment discrimination is one of the finest differentiating abilities that the eye possesses.

Contrast Sensitivity

In the present investigation, the major theoretical interest focuses on changes in visual sensitivity based on neural or cortical functions, as these mechanisms lend support to the unitary model of sensory regulation. Therefore, the most appropriate measures of interocular changes in visual sensitivity are those which test the

performance of the visual pathways and visual areas of the brain as brought about by monocular occlusion. For example, the contrast sensitivity function (CSF) provides a general index of the visual system's ability to process a wide range of contrasts. On the other hand, measurement of Snellen acuity represents only one domain of our visual function, that of high contrast and high spatial frequency (Hess, 1981). Deficits in contrast sensitivity are frequently linked to specific neural problems such as multiple sclerosis (MS) (Regan, Raymond, Ginsburg, & Murray, 1981). Hence, the CSF may demonstrate how well cortical neurons are operating. Contrast-threshold measurement is also a very sensitive indicator of subtle changes in visual performance (Hess & Woo, 1978). In a comparison of contrast thresholds for a range of different spatial frequencies with acuity tests for subjects with unocular cataract, Hess and Woo found that acuity tests grossly overestimated visual function for some subjects. Many of the subjects showed low-spatial-frequency abnormalities. Acuity tests only measure the smallest-sized, high-contrast object capable of being resolved, or the "limit of vision" (Hess & Woo, 1978, p.428), but do not assess the quality of vision for object sizes within the resolution limit. The contrast sensitivity function measures the relative visibility for object sizes within the resolution limit because it allows the measurement of contrast thresholds for a wide range of object sizes (spatial frequencies). Therefore, the CSF is superior to acuity tests because it is able to detect intra-resolution limit abnormalities.

Campbell and Robson (1968) measured the contrast sensitivity by presenting sine-wave gratings at a number of different spatial

frequencies generated on a oscilloscope screen to subjects who were instructed to adjust the contrast until the gratings were just visible. Using this method, contrast sensitivity can be plotted. The CSF forms an inverted-U-shaped function, with vision most sensitive to intermediate spatial frequencies of 3 cycles per degree (c/deg) and less sensitive to lower and higher frequencies (see Figure 1). Due to the contrast sensitivity falloffs at intermediate spatial frequencies, large changes in contrast threshold will result in relatively small changes in acuity: in some cases a 40% change in contrast thresholds results in an approximately 7% acuity change (Campbell & Green, 1965).

Recent studies (Kulikowski & Tolhurst, 1973; Keeseey, 1972) have provided evidence of two independent perceptual subsystems for the detection of spatio-temporal contrast: "sustained channels" which respond best to high spatial and low temporal frequencies, and "transient channels" which respond best to low spatial and high temporal frequencies. The different sensitivities of these two types of channels are held to be responsible for the difference between the CSF obtained with static stimuli and that obtained with temporally modulated or moving patterns (Robson, 1966). The sensitivity of the transient channels reduces or abolishes the low spatial frequency cutoff in the CSF, when there is temporal modulation. For low spatial frequencies less movement is required for detection. It has been suggested that these two perceptual systems are analogous to the X (linear) and Y (nonlinear)-cells of the cat's visual pathway (Enroth-Cugell & Robson, 1966). Although many investigations have described a variety of characteristics which classify X and Y cells into distinct groups, a

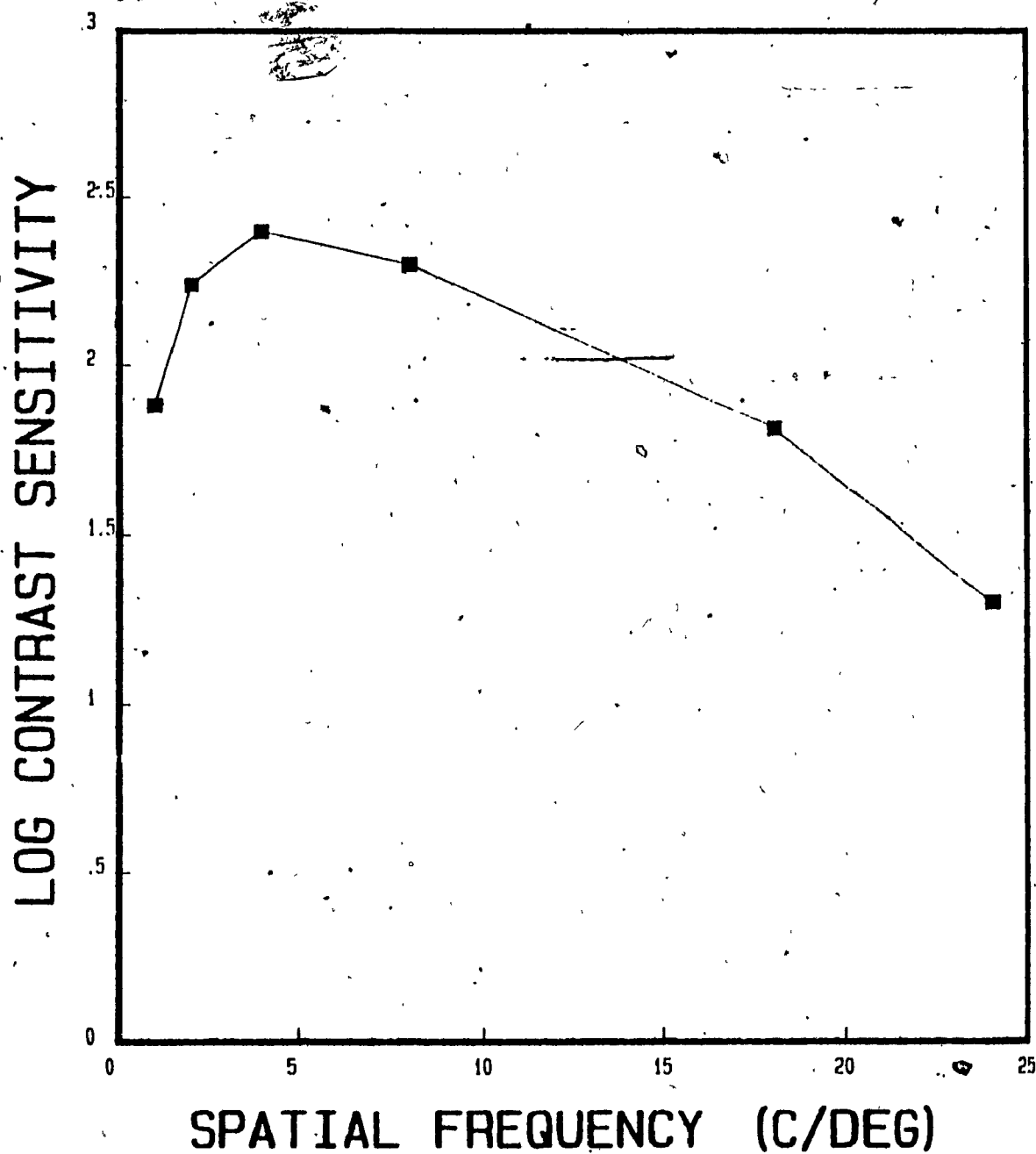


Figure 1. A typical contrast sensitivity function (CSF) for human foveal vision. (After "A new contrast sensitivity vision test chart". By A.P. Ginsburg, 1983, American Journal of Optometry & Physiological Optics, 61, p. 405).

recent review by Hochstein (1979) suggests that the X/Y classification might not be bimodal but rather continuous.

Present Study

The present investigation is a follow-up to a study by Mapp (1981), on the temporal changes in the CFF as a function of alternating monocular occlusion. In Mapp's study, subjects were confined for two days. During the first day, readings were taken from the nonoccluded eye at 0, 3, 6, 9, 12, and 24 hours, after which the patch was switched and thresholds were recorded from the other eye at the same time periods during the second day. The results indicated the depression-enhancement phenomenon during the first 24 hours succeeded by an immediate enhancement effect upon switching the occluder to the other eye. However, the increased sensitivity disappeared by mid-way through the second day. Mapp suggested that this occurrence was due to the originally unpatched eye remaining supersensitive even while occluded, which would be expected from a theory of central mediation. The newly nonoccluded eye showed an immediate increase in the CFF, but since the occluded eye was still supersensitive the nonoccluded eye reversed to its original baseline measure which avoided a state in which both eyes would be more sensitive than normal - a condition not congruent with the goal of a compensatory mechanism that strives to maintain an overall optimal level of input. Mapp concluded that interocular compensation appears to be a centrally mediated process, which tries to maintain an optimal level of stimulation from the visual system.

In the present study, spatial contrast sensitivity was used to measure the interocular effects of 24 hours of monocular occlusion, in

an attempt to further investigate the central mechanisms assumed to be involved in interocular compensation. Contrast sensitivity was chosen for several reasons: the measure can be administered quickly and easily, it is sensitive to very small changes in threshold (Campbell & Green, 1965), and it can be presented either spatially or temporally, which, therefore, can provide data for comparisons of spatial and temporal mechanisms of the visual system. ○

Based on previous research, it was hypothesized that the experimental subjects undergoing 24 hours of monocular deprivation would show the depression-enhancement effect in sensitivity to sine-wave gratings, whereas control subjects would show no change in visual sensitivity.

Method

Experiment 1

Subjects

The subjects were 10 female university students ranging in age from 19 to 26 years (Mean = 22.8), recruited by announcements posted throughout the university, and paid for their participation in the experiment. The subjects were either emmetropic or corrected for their refractive errors to 20/25 or better, and randomly divided into an experimental and control group, each initially consisting of four subjects. Due to early observations which indicated that not only the experimental subjects, but also the control subjects demonstrated an improvement in contrast sensitivity, two additional control subjects were run confined to the laboratory without undergoing monocular occlusion. This technique was used to assess the possibility that contrast sensitivity improves over time regardless of monocular occlusion, or whether an uncontrolled factor in the environment of the original control subjects was affecting the results.

Materials

The experimental subjects were fitted with a standard black eye patch and, to prevent any light leaks, a black mask covering their forehead from the hair line to the upper lip and reaching from ear to ear with a hole cut out over the other eye to permit monocular vision.

Contrast sensitivity was used as the dependent measure. Contrast sensitivity is visual sensitivity to patterns, usually sine-wave gratings, in terms of two variables: spatial frequency and contrast. A sine-wave grating is a repeated sequence of dark and light bars whose

luminance profile varies sinusoidally with distance about a mean luminance (Ginsburg, 1981, p. 71). The luminance difference of the dark and light bars determines the contrast of the grating. The width of one dark and one light bar of a grating is one cycle. The reciprocal of the cycle is the spatial frequency—the number of cycles of the grating that occur over some specified distance. The spatial frequency of an object is expressed by cycles per degree of visual angle (c/deg).

Spatial contrast sensitivity was measured by the Vistech Contrast Sensitivity Test System (Model 6000). The system consists of three test charts each displaying five rows of seven different sine-wave gratings of decreasing contrast and a blank for each of the five spatial frequencies. The first seven patches decrease in level of contrast for one spatial frequency and the last patch is a blank. These patches present a random order of the sine-wave gratings at one of three orientations: 15 degrees to the right, 15 degrees to the left, or vertical. The five spatial frequencies measured at the standard testing distance of 45.7 cm are 1.5, 3, 6, 12, and 18 cycles per degree (c/deg). The luminance of the test charts was 18.6 cd/m².

Procedure

The experimental subjects were required to live in the laboratory for 24 hours. They were run two at a time to prevent social isolation. The laboratory consisted of a large room containing beds, chairs, tables, and a television set. The subjects wore an eye patch and mask over their dominant eye, which was determined by the finger pointing method (Porac & Coren, 1975). The dominant eye was occluded because earlier research has demonstrated that the nondominant eye shows a

greater increase in sensitivity after deprivation (Bross & Zubek, 1972). During the 24-hour period, contrast sensitivity was measured in six testing sessions from the nonoccluded eye at 0, 3, 6, 9, 12, and 24 hours. The subjects were tested on the three test charts, which were presented in random order for each of the six testing sessions. For each row, the subjects were required to identify the orientation of eight spatial frequency gratings, or whether a spatial frequency grating was present, by responding "left", "right", "straight", or "blank". For each subject, the responses were recorded and averaged for the three test charts for each of the five spatial frequencies.

The control subjects were not confined to the laboratory, but run concurrently and reported for testing at the same times as the experimental subjects. During the testing, their dominant eye was occluded. The testing procedures were the same as those described for the experimental group.

Results

The data from the contrast sensitivity measure were analyzed as differences in log sensitivity between the first session (0 hour) and the subsequent 5 sessions (3, 6, 9, 12 and 24 hours). Figure 2 shows the mean temporal deviations from baseline log sensitivity averaged across spatial frequency for the nonoccluded eye of four experimental subjects relative to the corresponding eye of four control subjects. The two confined control subjects were not included in the analysis because there appeared to be no difference between the confined and non-confined control subjects, which is consistent with previous research (Bross & Zubek, 1975; Harper & Bross, 1978; Milstein & Zubek, 1971). A 3-way analysis of variance (one between and two within subjects design) was conducted on the variables, condition, session, and spatial frequency. The ANOVA summary table is shown in Table A-1 in Appendix A. There were no significant main effects or interactions.

Figures 3 and 4 show the mean log contrast sensitivity for Session 1 (0 hour) and Session 6 (24 hours) for the experimental subjects and control subjects, respectively. Standard error bars are shown in the Figures. The mean log contrast sensitivity scores and standard deviations for the experimental subjects are shown in Table B-1 and the scores and standard deviations for the control subjects are shown in Table B-2 of Appendix B.

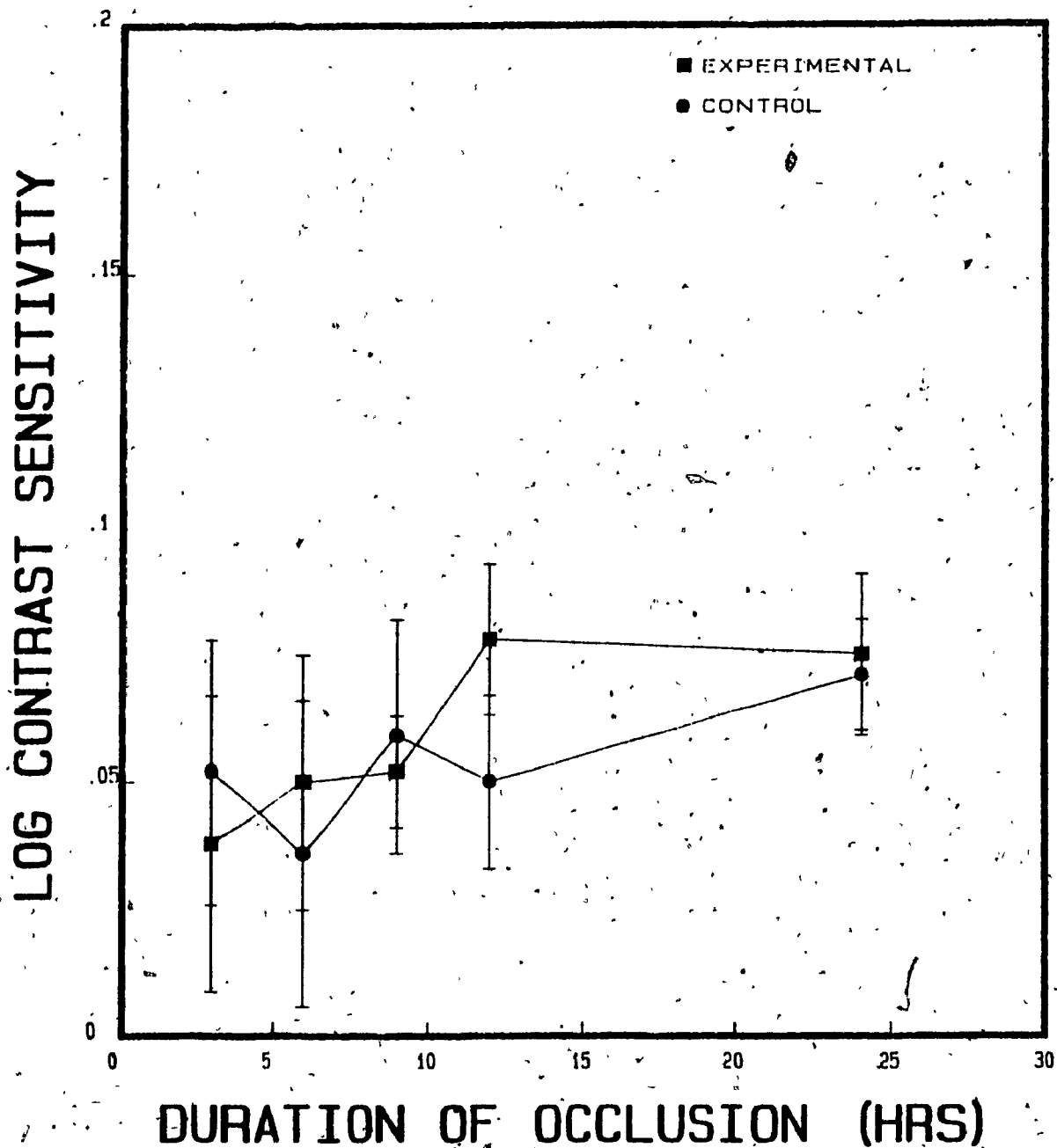


Figure 2. Experiment 1, - Mean temporal deviations from baseline log sensitivity averaged across spatial frequency for experimental and control subjects. Standard error bars are shown.

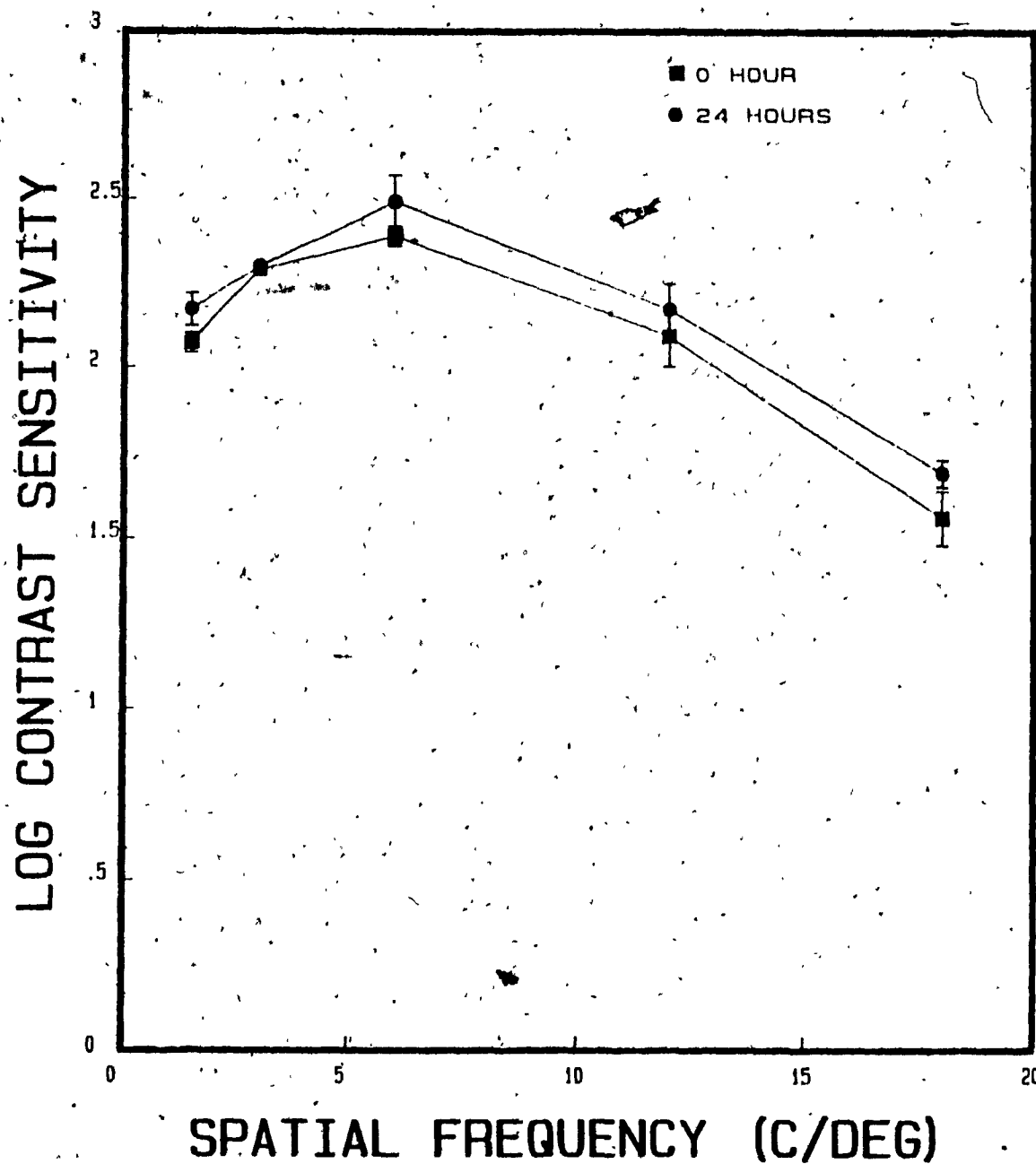


Figure 3. Experiment 1 - Mean log contrast sensitivity for Session 1 (0 Hour) and Session 6 (24 Hours) for experimental subjects.

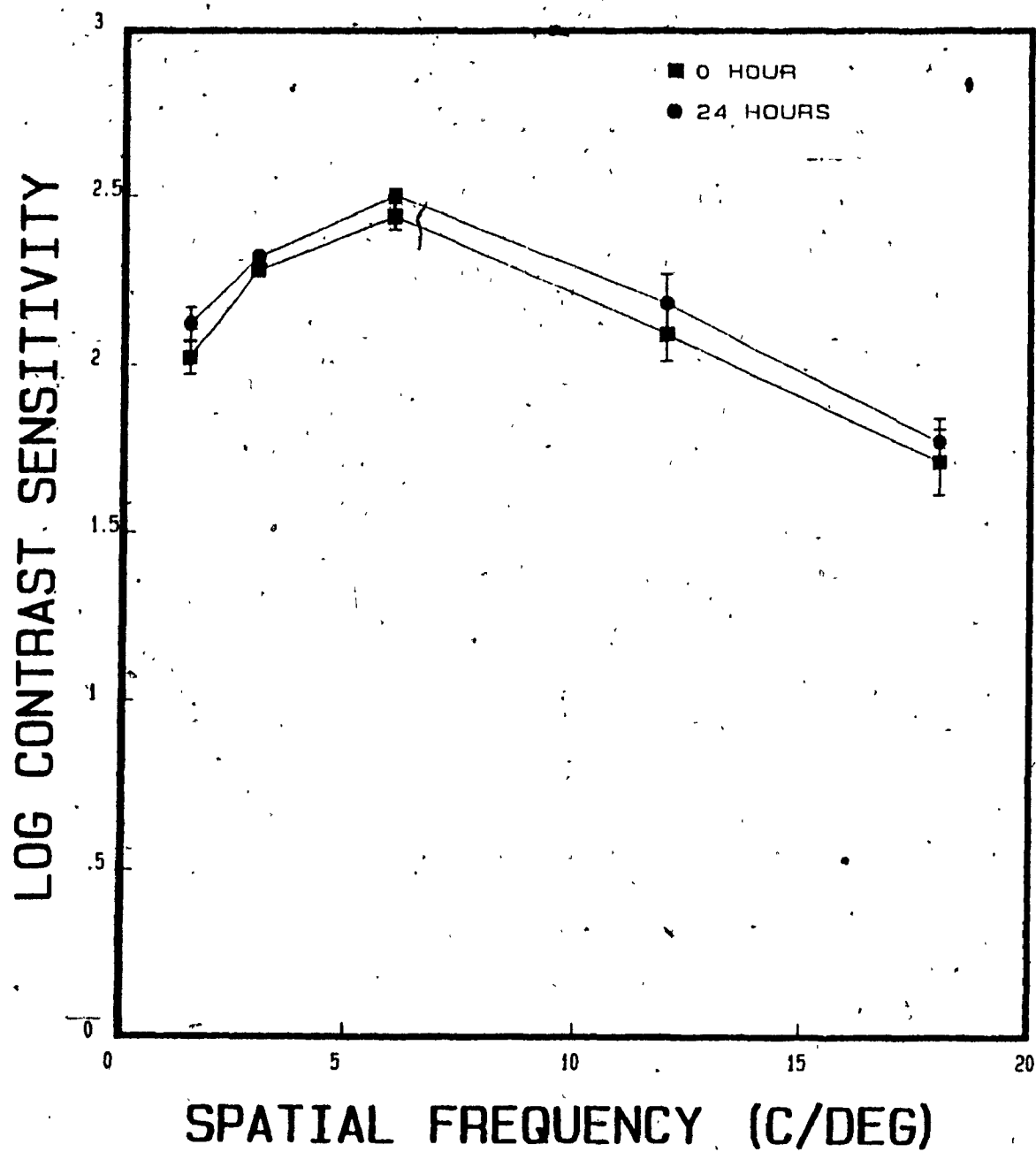


Figure 4. Experiment 1 - Mean log contrast sensitivity for Session 1 (0 Hour) and Session 6 (24 Hours) for control subjects.

Discussion

The original hypothesis that experimental subjects undergoing 24 hours of monocular occlusion would show the depression-enhancement effect in sensitivity to sine-wave gratings; whereas control subjects would show no change in visual sensitivity, was not supported. However, the results presented in Figure 2 indicate that a potential practice effect was present, as both the experimental and control subjects exhibited enhanced sensitivity after the first (baseline) testing period.

A drawback of the Vistech Contrast Sensitivity Testing System is that the design of the test charts makes it difficult to test the spatial frequencies in a truly random order. Each chart is designed so that the five rows of spatial frequencies are arranged from low to high frequencies: 1.5 c/deg is always the top row, followed by 3, 6, 12, and 18 c/deg. During testing, many of the subjects reported that they felt fatigued by the last row, which could lead to inaccurate responses at the higher spatial frequencies. Also, there is only one blank patch in each row, and this patch always falls in the eighth and last position.

To remedy the potential problems with the test's design, a second experiment was conducted using a computer-generated contrast sensitivity measure which could be programmed for random presentation of a wide range of spatial frequencies. In addition, the second experiment provided data for an evaluation of an alternative psychophysical method. The Vistech Contrast Sensitivity Testing System utilizes the forced-choice procedure, whereas the measure in the second experiment uses the Bekesy Tracking Method.

Experiment 2

As the first experiment had demonstrated that both experimental and control subjects showed enhanced sensitivity to sine-wave gratings over baseline values during a 24-hour period of monocular occlusion, a second experiment was designed to investigate whether this enhancement was indicative of factors relating to the Vistech Contrast Sensitivity Testing System itself, or whether similar changes would be seen with a different contrast sensitivity measure.

Method

Subjects

The subjects were 24 female university students, ranging in age from 19-28 years (Mean = 21.6). The subjects, recruited by announcements posted throughout the university, were randomly divided into an experimental and control group, each containing 12 subjects. All subjects were either emmetropic or corrected for their refractive errors to 20/25 or better, and they were paid for their participation in the experiment.

Materials

The equipment included a standard black eye patch, which was worn over the dominant eye of each experimental subject. The eye patch worn by the experimental subjects for 24 hours was held in place with white surgical tape covered by black electrical tape to prevent light leaks. The black masks which were used in Experiment 1 were replaced with the tape because the subjects had complained about the discomfort of the masks.

The Nicolet Contrast Sensitivity Testing System (CS 2000) used in

this experiment is a computerized measure of the contrast sensitivity function (CSF). This testing system is a flexible, programmable instrument which is capable of a variety of testing options including three psychophysical methods (Method of Adjustment, Method of Increasing Limits, and Bekesy Tracking Method), four types of stimulus patterns (moving, flickering, stationary, and mixed), and a wide range of spatial frequencies in either sine or square wave gratings (up to 22.8 c/deg). Testing can be interrupted and resumed freely throughout the test, and additional "probe" trials can be initiated at the end of a test, or to rerun an entire test.

The Nicolet CS 2000 was programmed to randomly test seven spatial frequencies: 0.5, 3, 6, 12, 15, 18, and 21 c/deg as the dependent measure. The psychophysical method employed was the Bekesy Tracking Method (Bekesy, 1967), a variation of the staircase technique. Before testing of any grating, subjects were shown that grating for three seconds. After the preview, grating contrast was reduced to 0 for 3 seconds. Contrast then automatically increased at a fixed rate of 0 to 0.50 contrast in 30 seconds. As soon as the grating was detected, the subject pressed the pushbutton, which reduced the contrast. When the grating could no longer be detected, the subject released the pushbutton which automatically triggered the contrast to increase. A trial consisted of six reversals in contrast for one grating. After each trial, the Nicolet CS 2000 automatically calculated the mean and standard deviation, and the built-in thermal printer provided a hard copy of the results. The standard method of calibration was used which set the display monitor (width = 22.5cm) for 100 cd/m² luminance, and

0.50 peak contrast (both measured at screen center). The viewing distance was 3 meters.

Procedure

The 12 experimental subjects were required to stay, two at a time, in the laboratory for 24 hours. During the 24-hour period, as in Experiment 1, contrast sensitivity was measured from the nonoccluded eye at 0, 3, 6, 9, 12, and 24 hours. The subjects were required to push the response button down when they could first see the sine-wave grating as it faded into view and to release it when the grating disappeared. During each testing session, the subject's means and standard deviations were recorded for each of the seven spatial frequencies.

The control subjects were not confined to the laboratory, but were run concurrently and reported for testing at the same times as the experimental subjects. During the testing sessions, their dominant eyes were occluded. The testing procedures were the same as those described for the experimental group.

P

Results

As in Experiment 1, the data from the contrast sensitivity measure were analyzed as differences in log sensitivity between the first session (0 hour) and the subsequent 5 sessions (3, 6, 9, 12, and 24 hours). Figure 5 shows the mean temporal deviations from baseline log sensitivity averaged across spatial frequency for the nonoccluded eye of 12 experimental subjects relative to the corresponding eye of 12 control subjects. A 3-way analysis of variance (one between and two within subjects design) was conducted on the variables, condition, session, and spatial frequency. The ANOVA summary table is shown in Table A-2 of Appendix A. The results were consistent with Experiment 1. There were no significant main effects or interactions.

The mean log contrast sensitivity for Session 1 (0 hour) and Session 6 (24 hours) for the experimental subjects and the control subjects are shown in Figures 6 and 7, respectively. The mean log contrast sensitivity scores and standard deviations for the experimental subjects are reported in Table B-3, and the scores and standard deviations for the control subjects are in Table B-4 of Appendix B.

As the above ANOVA was computed on deviations from baseline, a second ANOVA using raw scores from all test sessions was conducted. This analysis revealed significant main effects for Session, $F(5, 110) = 3.63$, $p < .01$, and Spatial Frequency, $F(6, 132) = 115.68$, $p < .01$ (see Appendix A, Table A-3).

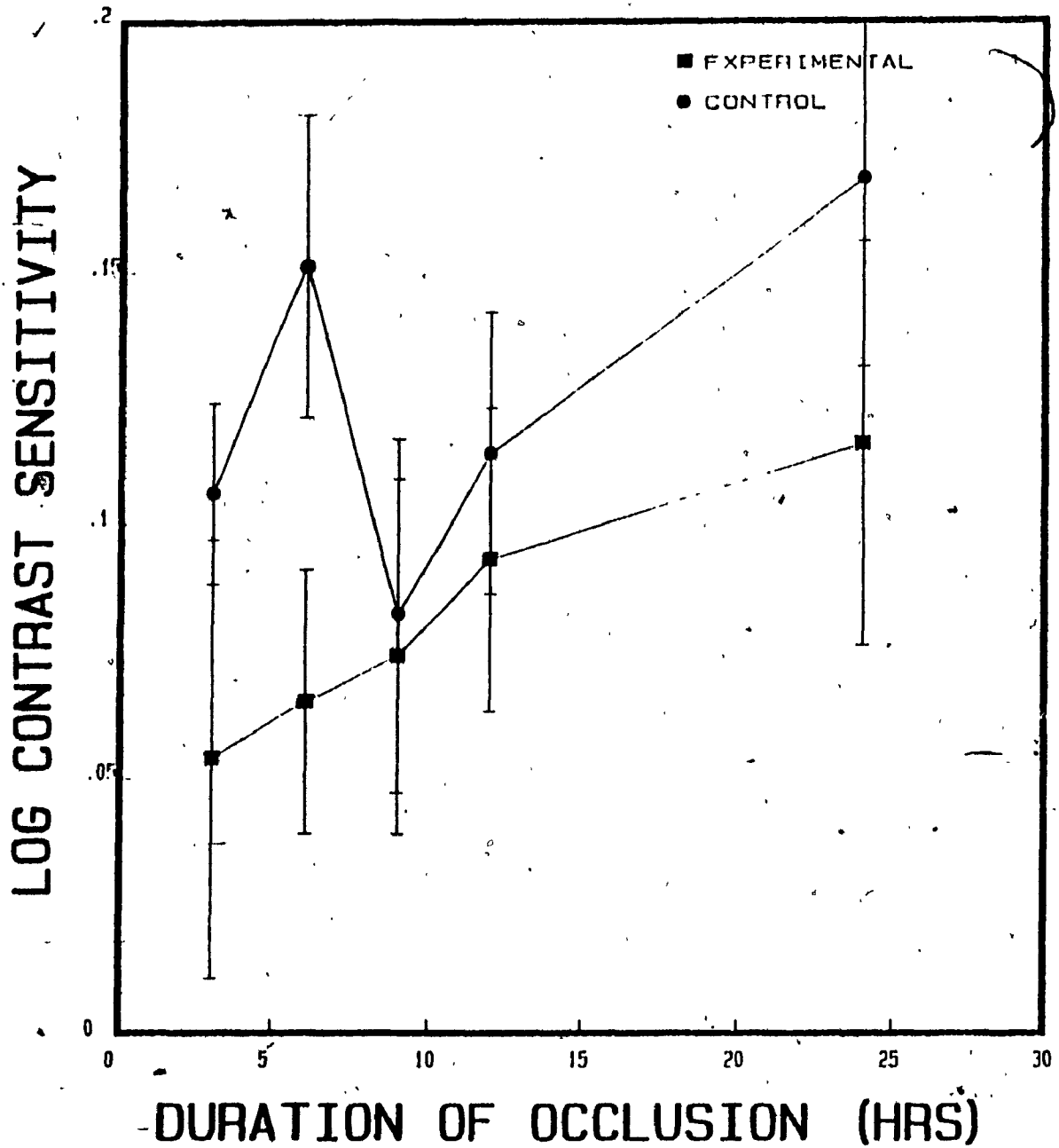


Figure 5. Experiment 2 - Mean temporal deviations from baseline log sensitivity averaged across spatial frequency for experimental and control subjects.

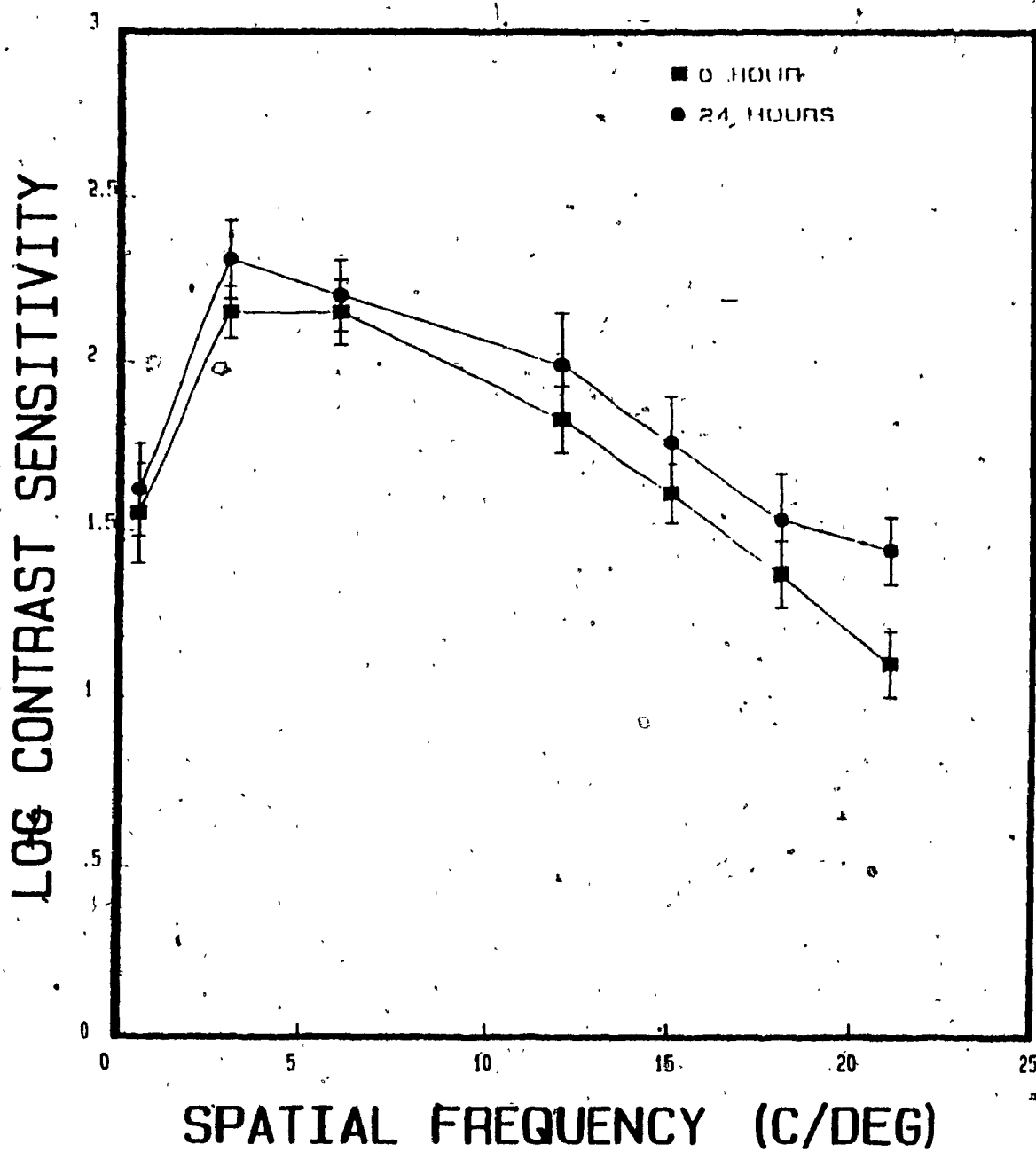


Figure 6. Experiment 2 - Mean log contrast sensitivity for Session 1 (0 hour), and Session 6 (24 hours) for experimental subjects.

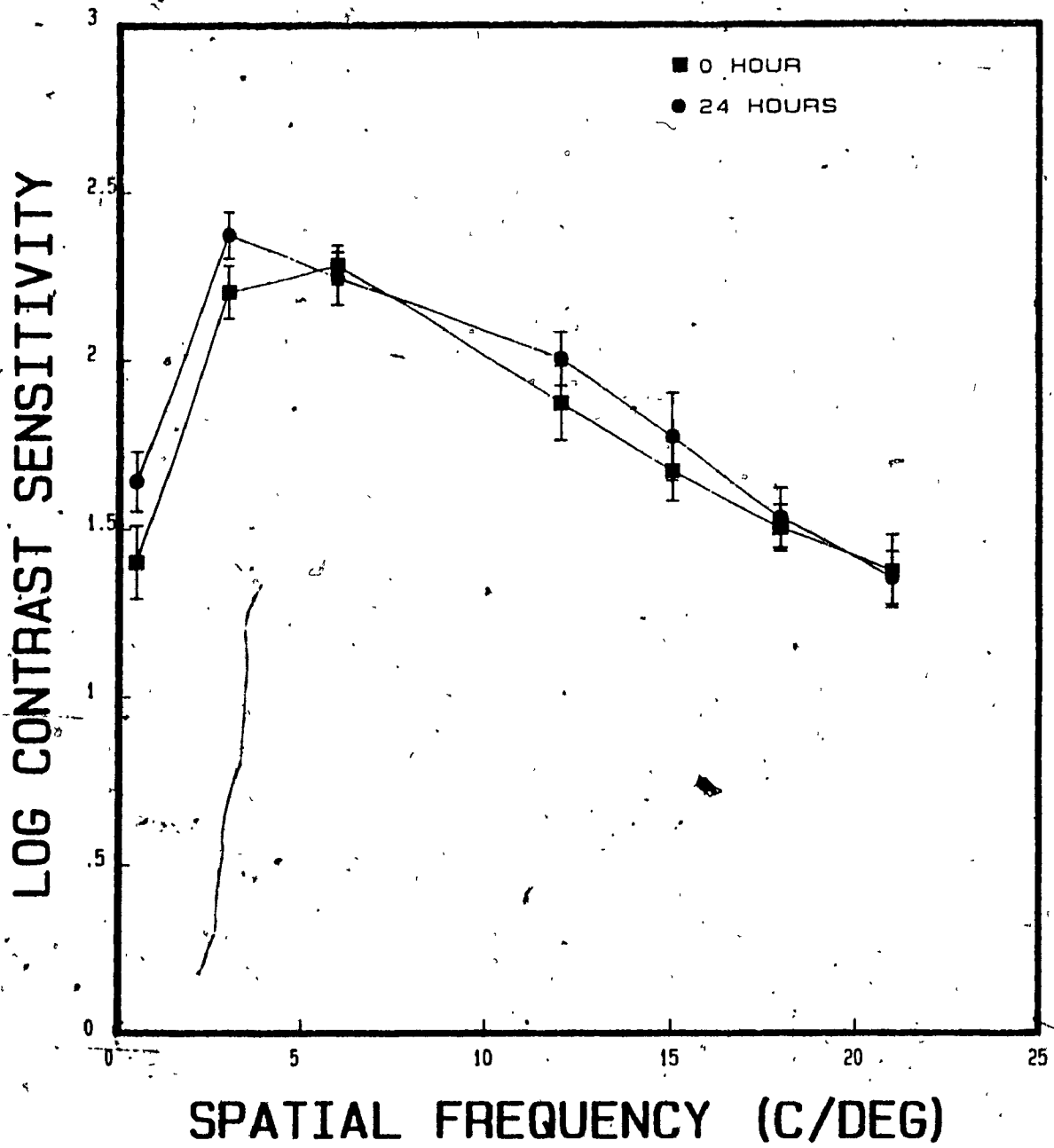


Figure 7. Experiment 2 - Mean log contrast sensitivity for Session 1 (0 Hour) and Session 6 (24 Hours) for control subjects.

Discussion

In both Experiment 1 and Experiment 2, the original hypothesis that experimental subjects undergoing 24 hours of monocular occlusion would demonstrate the depression-enhancement effect in contrast sensitivity, whereas the control subjects would show no change in sensitivity was not supported. Both the experimental subjects and the control subjects showed a trend towards increased sensitivity to sine-wave gratings, but there was no significant difference in this trend between the experimental and control groups.

A possible explanation for the lack of the depression-enhancement phenomenon in the experimental group is that the contrast sensitivity tests used in Experiment 1 and 2 were both spatial measures as opposed to temporal measures. Perhaps the neural or cortical mechanisms assumed to be involved in sensory compensation were not tapped by these measures. Previous research in sensory restriction has demonstrated that temporal measures are more susceptible to sensory compensation than absolute measures (Duda & Zubek, 1965). Bross and Zubek (1976) suggest that the enhancement effects observed on sensory measures of a temporal nature are mediated by the phasic components of the receptor systems. As stated in the Introduction, there is physiological evidence for the presence of two subcomponents within the visual sensory system, one tonic and one phasic (Enroth-Cugell & Robson, 1966), perhaps mediated by X-cells and Y-cells, respectively. Ikeda and Wright (1972) have reviewed the differences in the properties of these two classes of neurons, two of which are of interest to the present discussion. First, the tonic cells respond with sustained discharges to the presentation of

stimuli indicating that the tonic cells are maximally responsive to stationary stimulation, while the phasic cells give transient discharges at the onset and offset of a stimulus indicating that they respond maximally to temporally modulated stimuli. Secondly, there are differences in the fiber pathways associated with these cells. The tonic or sustained cells seem to project only to the visual cortex via the lateral geniculate body, while the phasic or transient cells project also to other subcortical structures, including the reticular formation. Since the phasic components provide the most direct and profuse interconnections with the reticular formation, the integrative homeostatic mechanism, any compensatory changes will be primarily reflected in the phasic systems. In light of these considerations, the different results between temporal and spatial measures of sensory sensitivity can be accounted for by the difference in mediation by either the phasic or tonic components. This model of subcomponents of the visual sensory system provides an explanation consistent with previous psychophysical evidence from studies of sensory deprivation and with the data from the current investigation.

One study which contradicts this interpretation of the visual system is the study by Freeman and Bradley (1980) cited in the Introduction. This study provides evidence that functionally monocular subjects have significantly higher vernier acuities than normal binocular subjects tested through one eye, which the authors suggest may be due to neural recruitment as a result of monocular deprivation. The vernier task is a spatial measure of visual sensitivity, and would therefore be mediated by x-cells, or the tonic system, according to the

organization of the visual subcomponents delineated by Ikeda and Wright. However, an alternative explanation is related to the fact that the normal vernier capacity is very sensitive (Berry, 1948), which might be reflected in greater changes in sensitivity as compared to less sensitive measures of visual function. Perhaps the presence or absence of compensatory changes in the visual system is dependent not only upon spatial versus temporal mechanisms, but also the degree of sensitivity of the measure used. This interpretation is consistent with Hochstein's suggestion that the characteristics which classify X and Y cells into two groups are not strictly bimodal (1981). A follow-up to the present investigation utilizing a temporal measure of contrast sensitivity might help to clarify these issues.

Since the results obtained from the second ANOVA on the raw scores for Experiment 2 indicate a significant increase in contrast sensitivity, this suggests that there is a practice effect present between 0 to 24 hours. This holds for both the experimental and control subjects in both Experiment 1 (see Figures 3 and 4) and Experiment 2 (see Figures 6 and 7) which suggests that the increase is not a function of monocular occlusion, or a factor inherent in the design of the Vistech Contrast Sensitivity Testing System used in Experiment 1, but may indicate a general practice effect in contrast sensitivity testing.

Indeed, other researchers have observed a similar improvement in sensitivity to sine-wave gratings after repeated trials. In a study addressing the question of independence of multiple spatial-frequency channels of the visual system, De Valois (1977) examined the effect of adaptation to a high-contrast sinusoidal grating on a large range of

frequencies. The results indicated that adaptation produces a decrease in sensitivity for frequencies centered around the adaptation frequency (less than 1 octave) and an enhanced contrast sensitivity for frequencies further removed, peaking at about 2.75 to 3 octaves. More importantly, De Valois found that long-term practice produced significantly higher contrast sensitivity functions and narrower bandwidths of the adaptational sensitivity loss. Assuming that detection is based on a pooled response of many cells which differ in their characteristic frequencies and bandpass characteristics, De Valois suggests that with increasing practice, a subject simply becomes more efficient at restricting the sample pool to those cells which are most sensitive to the frequency being observed, "in essence, selectively attending to different types of detectors" (p. 1064). De Valois concludes that the change in the adaptation effect and the general increase in the contrast sensitivity function over time suggest that her experiment and similar psychophysical experiments cannot be taken as "simple, direct reflections of a simple, unvarying, underlying physiological organization" (p. 1064).

Another experiment found a similar enhancement in contrast sensitivity over time. Fiorentini and Berardi (1981) investigated the effects of practice in the discrimination of briefly flashed gratings by a forced choice procedure. The tasks required discrimination either of pairs of complex gratings of different waveforms or of single (sinusoidal) gratings of different spatial frequencies. They found that in tasks involving discrimination of complex gratings the percentage of correct responses progressively increased with repetition of trials up

to 100-200 trials and then leveled off (at an unspecified level), and that the effect of practice was retained almost completely during experimental sessions one and two days after the first session. One subject retested six weeks after the first session without any further training, and another subject tested after seven months were both found to have partial retention of the effects of the initial practice. However, the effects of previous training did not transfer to the discrimination of patterns either of different orientation ($\pm 90^\circ$) or spatial frequency (± 1 octave) while transfer was obtained for smaller orientation ($\pm 30^\circ$ or less) and spatial frequency changes ($\pm 1/2$ octave). In Experiment 1, the forced-choice technique was used and the orientation ($\pm 15^\circ$) changes from trial to trial fell within the ranges where the transfer of learning was observed in the study by Florentini and Berardi. Since discrimination was assessed with a forced choice procedure in Experiment 1 and in the study by Florentini and Berardi, the trend towards enhanced sensitivity with training could not be attributed to a shift in the criterion of the subject (Baird & Noma, 1978), and could, therefore, be considered as perceptual learning (Gibson, 1953).

Through a review of the literature on perceptual learning, Gibson summarizes the evidence of improvements in perceptual judgements by practice. This evidence can be found in a variety of experimental designs including those requiring absolute and relative judgements in perceptual tasks. Improvements have been observed in foveal visual acuity (McFadden, 1941), peripheral visual acuity (Low, 1946), lower limen for pitch of tones (Guilford, 1936), and relative discrimination

of pitch (Connette, 1941).

Gibson also discusses factors which influence these improvements. It is evident that improvement in perceptual judgement occurs with practice, but the relation between amount of practice and degree of improvement is unclear. According to Gibson, there will not be one general learning curve, but many curves, depending on the experimental design. However, many studies have shown that frequency is a significant variable (Bevan & Zener, 1952; Seward, 1931; Tresselt, 1947), and that early practice is more effective than later stages of practice (Fernberger, 1916). These observations could be relevant to research conducted in sensory deprivation. In the present investigation, changes in sensitivity were determined by comparing contrast sensitivity scores at five testing sessions over 24 hours to an initial baseline value taken at the first testing session (0 Hour). However, this baseline reading may not have been accurate. In light of the evidence of improvements in perceptual judgements with practice, future investigations could benefit from submitting subjects to extensive practice with the contrast sensitivity measure prior to taking baseline readings. This technique could help to clarify whether changes in sensitivity are due to practice or reflect some neurological mechanism in sensory compensation.

Gibson describes perceptual learning as a process by which invariant features of the stimulus array are successively differentiated by more and more discriminative responses. In the stimulus-response (S-R) relationship, the stimulus variable is spread along a continuum. In the beginning of a hypothetical experiment, the band of stimulation

which may elicit a particular response is originally very wide and the S-R relationship is not very specific. After training, the band of stimulation which may elicit a response is narrower; the S-R relationship has increased in specificity. The effectiveness of progressive practice suggests that a quality of the stimulus not responded to in isolation is being "differentiated from the total stimulus input and utilized as a cue variable" (Gibson, 1953, p. 123). In the case of increased visual acuity, observers learn to respond to reduced cues by learning what the fragmentary stimuli represent. Gibson's model is consistent with De Valois' explanation of higher contrast sensitivity functions with practice, and helps to explain the results in the present investigation.

If perceptual learning is a factor in contrast sensitivity testing, the ability of these tests to evaluate and monitor visual anomalies comes into question. Further research is needed to quantify the degree of improvement possible after varying amounts of trials and durations between trials.

The present investigation utilized contrast sensitivity as the measure of sensory sensitivity in an attempt to further support the model of central mediation of sensory compensation as a function of sensory restriction. Although this investigation did not support the unitary model of sensory regulation postulated by Bross et al. (1981), the need for additional research in this area is clear. The evidence of the two subcomponents of the visual system which mediate temporally modulated and sustained measures indicate the need of further studies using temporal measures of contrast sensitivity.

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Appendix A

Summary Tables of Analysis of Variance

Table A-1

Experiment 1: Summary of analysis of variance, mixed design (deviation scores).

Source	SS	df	MS	F
Between-S				
Cond	.001	1	.001	.01
Error	.443	6	.074	
Within-S				
Sess	.024	4	.006	.82
Sess x Cond	.011	4	.003	.36
Error	.175	24	.014	
Freq	.059	4	.015	1.08
Freq x Cond	.117	4	.029	2.15
Error	.326	24	.014	
Sess x Freq	.057	16	.004	.94
Sess x Freq x Cond	.058	16	.004	.95
Error	.367	96	.004	

Note. All F values are nonsignificant at $p < .05$.

Table A-2

Experiment 2: Summary of analysis of variance, mixed design (deviation scores).

Source	SS	df	MS	F
Between-S				
Cond	.403	1	.403	.57
Error	15.535	22	.706	
Within-S				
Sess	.457	4	.114	.98
Sess x Cond	.157	4	.039	.34
Error	10.259	88	.117	
Freq	1.262	6	.210	.76
Freq x Cond	1.212	6	.202	.73
Error	36.631	132	.278	
Sess x Freq	1.225	24	.051	1.46
Sess x Freq x Cond	1.111	24	.046	1.32
Error	18.459	528	.035	

Note. All F values are nonsignificant at $p < .05$.

Table A-3

Experiment 2: Summary of analysis of variance, mixed design (raw scores).

Source	SS	df	MS	F
Between-S				
Cond	.576	1	.576	.24
Error	52.270	22	2.380	
Within-S				
Sess	1.526	5	.305	3.63 *
Sess x Cond	.156	5	.031	.37
Error	9.245	110	.084	
Freq	111.367	6	18.561	115.68 *
Freq x Cond	.786	6	.131	.82
Error	21.179	132	.160	
Sess x Freq	1.012	30	.034	.93
Sess x Freq x Cond	1.233	30	.041	1.13
Error	23.950	660	.036	

* $p < .01$

Appendix B

Contrast Sensitivity Data

Table B-1

Experiment 1 - Mean log contrast sensitivity scores and standard deviations for experimental subjects

		Means					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
	1.5	2.07	2.05	2.07	2.14	2.13	2.17
Spatial	3	2.29	2.27	2.28	2.29	2.32	2.30
Freq.	6	2.39	2.49	2.45	2.47	2.47	2.49
(c/deg)	12	2.09	2.12	2.18	2.15	2.19	2.17
	18	1.56	1.69	1.69	1.64	1.70	1.69
Mean		2.08	2.12	2.13	2.14	2.16	2.16
		Standard Deviations					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
	1.5	.06	.03	.06	.09	.07	.08
Spatial	3	.00	.07	.06	.09	.04	.02
Freq.	6	.06	.14	.05	.08	.08	.13
(c/deg)	12	.16	.16	.18	.13	.17	.14
	18	.14	.08	.10	.11	.09	.07

Table B-2

Experiment 1 - Mean log contrast sensitivity scores and standard deviations for control subjects

		Means					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
	1.5	2.02	2.16	2.11	2.14	2.11	2.12
Spatial	3	2.28	2.29	2.31	2.34	2.30	2.32
Freq.	6	2.44	2.48	2.44	2.49	2.49	2.50
(c/deg)	12	2.09	2.15	2.19	2.15	2.10	2.18
	18	1.71	1.72	1.67	1.72	1.78	1.77
Mean		2.11	2.16	2.14	2.17	2.16	2.18
		Standard Deviations					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
	1.5	.08	.05	.07	.06	.10	.08
Spatial	3	.03	.00	.04	.06	.04	.02
Freq.	6	.08	.08	.08	.05	.05	.04
(c/deg)	12	.13	.14	.11	.17	.14	.15
	18	.17	.07	.11	.09	.14	.12

Table B-3

Experiment 2 - Mean log contrast sensitivity scores and standard deviations for experimental subjects

		Means					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
Spatial Freq. (c/deg)	.5	1.40	1.55	1.43	1.55	1.40	1.64
	3	2.20	2.33	2.27	2.17	2.27	2.37
	6	2.28	2.23	2.24	2.22	2.36	2.24
	12	1.87	1.80	1.97	1.94	1.96	2.00
	15	1.67	1.77	1.79	1.84	1.82	1.77
	18	1.50	1.64	1.64	1.61	1.67	1.53
	21	1.37	1.32	1.40	1.47	1.37	1.35
Mean		1.76	1.81	1.82	1.83	1.84	1.84
		Standard Deviations					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
Spatial Freq. (c/deg)	.5	.38	.32	.29	.40	.23	.30
	3	.27	.12	.20	.13	.16	.24
	6	.18	.25	.26	.22	.19	.25
	12	.36	.27	.28	.22	.27	.26
	15	.29	.32	.24	.33	.25	.42
	18	.24	.43	.51	.45	.34	.29
	21	.36	.35	.31	.46	.34	.28

Table B-4

Experiment 2 - Mean log contrast sensitivity scores and standard deviations for control subjects

		Means					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
Spatial Freq. (c/deg)	.5	1.55	1.57	1.60	1.53	1.52	1.62
	3	2.15	2.23	2.26	2.27	2.28	2.31
	6	2.15	2.20	2.24	2.22	2.23	2.20
	12	1.83	1.88	1.91	1.92	1.89	1.99
	15	1.61	1.69	1.74	1.66	1.74	1.76
	18	1.37	1.46	1.53	1.50	1.53	1.53
	21	1.10	1.25	1.24	1.30	1.32	1.44
Mean		1.68	1.75	1.79	1.77	1.79	1.84
		Standard Deviations					
		Duration of Occlusion (Hours)					
		0	3	6	9	12	24
Spatial Freq. (c/deg)	.5	.51	.43	.36	.35	.35	.46
	3	.28	.34	.28	.28	.29	.38
	6	.32	.41	.23	.38	.28	.36
	12	.34	.38	.36	.36	.46	.54
	15	.29	.44	.30	.37	.38	.45
	18	.34	.44	.29	.33	.35	.46
	21	.34	.39	.34	.37	.44	.35

Appendix C
Subject Instructions

Control subject: Subject participation agreement

Subject Name: _____ Social Insurance #: _____

I hereby agree to participate in this 24-hour study of the monocular visual system. Furthermore, I understand that I must arrive promptly at the times indicated on the schedule provided by the experimenter.

I understand that I will receive \$25.00 upon the completion of the 24-hour period for my complete participation in this experiment.

Signature: _____

Date: _____

Experimenter: _____

Control subject: Time schedule

You are expected to report to the Lab 307-81 promptly at the following times:

Date: _____

9:15 A.M.

12:15 P.M.

3:15

6:15

9:15

Date: _____

9:15 A.M.

Experimental subject: Subject participation agreement

Subject Name: _____ Social Insurance #: _____

I hereby agree to participate in this 24-hour study of the monocular visual system. I promise not to remove the experimental eye patch and mask under any circumstances. I also understand that I must report any light leaks so that the experimenter may make any necessary adjustments.

I understand that I will receive \$25.00 upon the completion of the 24-hour period for my participation in this experiment.

Signature: _____

Date: _____

Experimenter: _____

Post-Test Survey

I would be interested in receiving information on the outcome of this experiment.

Yes: _____

No: _____

My mailing address is: (Please print)

Name: _____

Address: _____

Code: _____

Phone: _____ (Day ___ Night ___) Age: _____

If more testing is necessary at a later date, I would be interested in serving as a subject again:

Yes: _____

No: _____

I prefer: (Check one, or both)

- 1. _____ To come into the laboratory for the entire 24-hour period.
- 2. _____ To come in every three hours to have my vision tested.

Additional comments: (Is there anything that you would like to see changed from a subject's point of view?) Use back if needed.

Signature _____ Date _____