THE EFFECTS OF MONOCULAR AND BINOCULAR INTERMITTENT STIMULATION ON STEREOSCOPIC JUDGMENTS

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ABSTRACT

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by

Diane L. Smolen

This study was undertaken to investigate the effects of intermittent illumination on stereopsis. Intermittent rates of 8Hz and 15Hz with pulse to cycle fractions of 1/4 and 3/4s were utilized. Two types of intermittent illumination were imployed, a monocular intermittent condition (only the illumination exposed to the observer's dominant sighting eye was intermittent, the non-dominant eye remained steady) and a binocular intermittent condition (both eyes were simultaneously exposed to the intermittency). A sphere-ring target was used with a forced choice judgment of either in front of or behind.

Results from four observers indicated that the monocular intermittent condition provided the expected decrement in the 8-10Hz range that previously yeilded impoverishment of visual acuity and unique changes in brightness, hue and saturation. The critical rate was 8Hz, PCF 1/4. The binocular intermittent condition also impaired the stereoscopic process. However, the critical rate did not occur in the 8-10Hz range, but at 15Hz, PCF 1/4. The monocular intermittent condition, at rate 8Hz with PCFs of 1/4 and 3/4 induced a greater number of mean errors than the binocular intermittent condition. At 15Hz and PCFs of 1/4 and 3/4s this reversed and the

binocular intermittent condition induced a greater mean error than the monocular intermittent condition.

It was concluded that present ideas relating visual acuity and stereopsis are in need of revision. If both processes are related then the effects of intermittency would be assumed to be similiar under the binocular intermittent condition.

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by

Diane L. Smolen

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TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

The present study was designed to investigate the effects of intermittent photic input on stereopsis. This study was an extension of the work started by Bartley and Bishop in the 1930's and continued by Bartley and his associates until the present time. Their area of concern has been two-fold: 1) the sensory or experiential effects of temporal manipulation and 2) a neurophysiological understanding of the body processes involved. They have felt that by learning how the temporal coding of input influences the resulting visual phenomenon, some clarifications of the underlying biological mechanisms serving visual perception can be made.

A brief summary of the work of Bartley and associates will depict the developing trend that resulted in this study.

During the 30's and early 40's Bartley was not only involved in neurophysiological recordings but also in sensory investigations. It was during this period that he pointed out the importance and uniqueness of resulting phenomena when using subfusional rates of intermittency as a means of temporal manipulation. Bartley discovered that by manipulating pulse rate and the so-called light/dark ratio (pulse-to-cycle-fraction, PCF) in various combinations, that the subjective brightness of an intermittent target would become greater than that of a steady target. (The light/dark ratio will not be used when refering to the stimulus input.) The phenomenon was defined as "brightness enhancement". The critical rates of intermittency involved for a maximum effect were between 8-10Hz and a PCF of less than 1/2. The neurophysiological explanation for brightness enhancement developed by Bartley was the Alternation of Response Theory. In short summary, the theory states that the visual mechanisms can respond to stimuli of any rate, but will respond most vigorously at a certain critical one, based upon the intrinsic periodicity of the system. (Bartley 1938;1939;1958) One of the side effects of the brightness enhancement studies had been the appearance of odd chromatic alterations and glitter. The next step in the long-range program of research was the investigation of part spectrum input. Bartley and Nelson (1960) found that when using Wratten filters for this purpose, color changes began to take place almost immediately as slow rates of intermittency were introduced. As rates were increased they noted hue shifts, changes in saturation and brightness. They called the desaturation phenomenon the washout effect. (Bartley and Nelson 1961)

Further investigation by Nelson, Bartley and Mackavey (1961), reported deterioration of normal color discrimination using Ishihara color charts under the same temporal conditions as those causing the washout effects. Maximum effects were induced at low rates and

PCF 1/8. Very low rates and rates approaching fusion reinstated discrimination. A tentative hypothesis was proposed to link the effect to differences in transmission rates for nervous activity initiated by various parts of the spectrum.

Ball (1964) initiated a quantitative investigation of the effects of intermittent stimulation on brightness, hue and saturation. He found maximum enhancement conditions to appear at 10Hz, PCF 1/4 and 500mu.

Ball and Bartley (1967) utilized intermittent illumination to view pseudoisochromatic test plates. In agreement with Nelson, Bartley and Mackavey (1961), red-green color deficiency was again induced or increased with low rates and PCFs less than 1/2. The interesting result of this study was a substantial improvement in performance for red-green color deficients when a PCF 3/4 was employed.

Another aspect in the program of investigation dealt with the temporal effects upon visual acuity. Based upon the assumption that intermittency increased the subjective brightness of a target some early workers, Senders (1949) and Nachimais (1958) hypothesized that the same conditions producing enhancement would also enhance visual acuity. However, Bourassa and Bartley (1965) showed that visual resolution was adversely affected under brightness enhancement conditions. The maximum impairement occurred at 10Hz, PCF 1/4 with monocular viewing of the target. Bartley, Nelson and Soules (1963) found that acuity decreased as temporally induced brightness was increasing, i.e. with PCF 1/4 and pulse rates below 10Hz a marked impairement occurred. In this study the targets were again viewed monocularly. Bartley and Ball (1968) used a standard Landolt C target which was viewed binocularly. They found the maximum decrement to be at 5Hz, PCF 1/4. It was proposed that the type of maximal synchronized activity that produced brightness enhancement interfered with the temporal coding of information necessary for other perceptual processes.

Various attempts have been made to investigate the effects of intermittent illumination on stereopsis. The initial study utilized a Howard-Dollman peg arrangement with essentially no resulting decrement. The second study utilized a disk-annulus target and again preliminary results indicated no significant change in comparision to the induced acuity decrement. (Bartley and Ball 1969) Since effects of intermittency on stereopsis were not found it was supposed that inappropriate experimental conditions had been used.

Theoretically acuity and stereopsis should not greatly differ in their susceptibility to temporal manipulation since stereoscopic acuity is correlated with the visual acuity of both eyes. Both acuity and stereopsis involve similar processes. The actual stimulus condition necessary for a stereoscopic judgment is retinal disparity. The disparate images are basically contours that demarcate the light dark areas of the retina which define objects or borders. (Ogle 1958) Ball (1968) attributed the acuity decrement to temporal interference with the neural processes responsible for contour, seeing target borders. Since temporal manipulation did impoverish visual acuity, the fact that the experimental investigations did not effect stereopsis was unexpected. Ogle (1958) felt that stereoscopic acuity would in general be influenced by those same factors that influence visual acuity.

A recent study done by Smolen, Grossman and Bartley (1971) indicated that a definite decrement in the stereoscopic process can be induced. A target consisting of a black ringed hole and a black mobile dot was used. The critical rate of intermittency was 8Hz, PCF 1/4. However, only the illumination exposed to the observer's dominant sighting eye was made intermittent. The illumination exposed to the observer's non-dominant eye remained steady causing the binocular-fused image to appear as though the intermittent component were superimposed upon a steady component. In this case, subjectively, the target appeared to be visually unaffected by the intermittency. Borders were clearly perceivable. Both of the previous studies were done with both eyes simultaneously exposed to the intermittent illumination.

The present study was undertaken in order to determine the effects of binocular intermittency on stereopsis as compared to the effects of the dominant sighting eye intermittency. Since previous investigations involving stereopsis utilizing binocular intermittency indicated no significant change the experimental equipment utilized by Smolen, Grossman and Bartley (1971) were adapted.

The two questions raised in the present study were a) whether or not binocular intermittency was a successful disrupter of the stereoscopic process and b) if binocular intermittency did induce a decrement in the observer's judgment, where would the decrement in the judgment occur.

Previous experimentation with stereopsis has indicated that impairment of the process occurred when the images of the two eyes were not equally manipulated. Green (1889) used prisms in front of one eye and explained the resulting distortion as being due to a changed relationship between the retinal images of the two eyes. Ogle (1948) found that distortions of stereoscopic spatial localizations occurred when a magnification lens was placed in front of one eye. Ogle (1958) determined that blurring of the retinal images would not result in a loss of stereopsis unless the blurring was extreme or blurred differentially in the two eyes.

METHOD

Subjects:

The observers were one undergraduate and three graduate students, all having normal stereoscopic ability (tested using a Verhoff stereopter). Two of the observers viewed the target at 12 feet, the other two at nine feet. Two different distances were used because all four observers were not able to make the discrimination at 12 feet. For two of the observers the binocular steady levels approached the chance level of 30 errors out of a possible 60. Thus, a nine foot viewing distance was utilized for them.

Apparatus:

The apparatus for the study consisted of three sections; 1) the eye piece, 2) the lighting system and 3) the target. The eye piece consisted of two 3" squares both of which had a 1/16" aperture. The squares slid in a track mounted to a 6-1/2" by 9" sheet of plexiglass which enabled the observer to adjust for interpupilliary distance, which was measurable. Thus consistent alignment was possible and directly in line with the midline of the target. The entire unit was supported by two rods clamped to a table and a cross bar. A chin rest was used to eliminate shifts in the observer's position.

A 750W projector served as the light source. The reflected luminance was calibrated at 80.75fl using the Prichard Photomoter. Directly in front of the projector was a 2" square mirror mounted at a 45 degree angle to the beam. A second 2" square mirror was diagonally supported between the two apertures of the eye piece again at a 45 degree angle to the beam. Thus the beam was directed back toward the target which was either 12 feet or nine feet from the observer. Both the projector and the first mirror were mounted on an optical bench which was aligned with the target midline. In this manner shadows were eliminated. (Figure 1)

The target was an 8" by 8" sheet of plexiglass with a 1-1/2" circular hole bordered by a 1/32" black ring. The target surround was painted with Eastman Kodack High Reflectance White. The variable element in the target was a 3/8" black sphere centered in the bordered circular hole. This sphere was on the end of a transparent rod which could be positioned so as to be in the same plane as the ring, or to be closer or farther away from the observer than the black ring.

Two pen moters with attached flags were mounted to the supportive framework of the eye piece so as to close off the apertures of the eye piece depending upon the flag position. This device provided for the intermittency. Frequency and duration were controlled by a Grass medical stimulator, Model S4. A Tektronix oscilloscope Type 503 enabled monitoring for proper frequency and duration.

Figure 1. Apparatus representing the target and the lighting system.

Procedure:

The observer's task was to make a judgment as to whether the black sphere was in front of or behind the black ring. The six positions of the sphere (3/8", 1/4", 1/8" both in front and behind the black ring) were presented ten times per session. Thus each session consisted of sixty judgments.. Each position was presented in a predetermined random order. Five conditions were utilized for frequency and duration- 8Hz with a PCF of 1/4; 8Hz, PCF 3/4; 15Hz, PCF 1/4; 15Hz, PCF 3/4 and a steady exposure. These rates and PCFs were presumed, on the basis of other work done in the laboratory to provide for brightness enhancement. In half of the sessions the dominant sighting eye was exposed to the intermittent illumination while the non-dominant eye was exposed to steady illumination (the monocular intermittent condition). In the remainder of the sessions both eyes were simultaneously exposed to the intermittent illumination (the binocular intermittent condition).

The random order of the conditions for each session was as follows:

session #1. 15Hz, PCF3/4- monocular intermittent condition
2. 8Hz, PCF1/4- monocular intermittent condition
3. 15Hz, PCF3/4- binocular intermittent condition
4. 8Hz, PCF3/4- binocular intermittent condition
5. 8Hz, PCF3/4- monocular intermittent condition
6. steady- monocular

7. steady- binocular
8. 15Hz, PCF1/4- monocular intermittent condition
9. 8Hz, PCF1/4- binocular intermittent condition
10. 15Hz, PCF1/4- binocular intermittent condition
11. steady- monocular
12. 8Hz, PCF3/4- monocular intermittent condition
13. 15Hz, PCF3/4- binocular intermittent condition
14. 15Hz, PCF1/4- binocular intermittent condition
15. steady- binocular
16. 8Hz, PCF1/4- monocular intermittent condition
17. 8Hz, PCF3/4- binocular intermittent condition
18. 8Hz, PCF1/4- binocular intermittent condition
19. 15Hz, PCF1/4- monocular intermittent condition
20. 15Hz, PCF3/4- monocular intermittent condition
21. 15Hz, PCF1/4- binocular intermittent condition
22. 15Hz, PCF1/4- monocular intermittent condition
23. 8Hz, PCF1/4- monocular intermittent condition
24. steady- monocular
25. 8Hz, PCF3/4- binocular intermittent condition
26. steady- binocular
27. 15Hz, PCF3/4- binocular intermittent condition
28. 8Hz, PCF3/4- binocular intermittent condition
29. 15Hz, PCF3/4- monocular intermittent condition
30. 8Hz, PCF1/4- binocular intermittent condition

The monocular steady sessions (steady illumination, the observer using only the dominant sighting eye) were included to periodically insure that extraneous "cues" were not interfering with the process, since stereopsis does not function monocularly. The binocular steady sessions (steady illumination, the observer viewing the target binocularly) established each observer's baseline error level for comparision of the effects of the other four conditions.

Once the experiment was in progress, there was no verbal communication. A buzzer system enabled the observer to signal his response. One buzz indicated a response of behind, two in front. A white card was placed between the observer and the target during the adjustment of the black sphere. This insured that the observer was not able to view the positioning of the sphere and also maintained a constant level of illumination and continual intermittency. Removal of the card signaled the observer to prepare to make the judgment.

Results:

The results are shown in Figures 2-5. The abscissa representing the rates of intermittent illumination is labeled in three ways: Hz, pulse duration and PCF. The ordinate indicates the mean number of errors per observer. For observers A, B and C each point is the mean of 180 trials (60 trials per session; three sessions per rate of intermittent illumination) plus and minus one standard error. For observer D each point is the mean of 300 trials (60 trials per session; five sessions per rate of intermittent illumination) plus and minus one standard error. Observers A and B viewed the target at a distance of nine feet, while the distance for observers C and D was 12 feet.

The mean number of errors for the binocular steady condition for each observer is that observer's baseline error level at the given experimental distance. The mean number of errors for the monocular steady condition represents each observers maximum or ceiling point error level as the stereoscopic process does not function monocularly.

Figure 2 represents the data for observer A. The target distance was nine feet. The mean error for all experimental conditions is greater than the mean error obtained for the binocular steady. Under the monocular intermittent condition the maximum mean error occurred at 8Hz, PCF 1/4 and decreased at 8-3/4 and 15-1/4 respectively.

The mean error rose at 15-3/4. Under the binocular intermittent condition the mean error was at a minimum at 8-1/4. The mean error rose at 8-3/4 and again at 15-1/4; at 15-3/4 a drop occurred. At 8-1/4 the monocular intermittent condition exhibited a greater mean error than the binocular intermittent condition. At 15-1/4 this reversed. The binocular intermittent condition exhibited a greater mean error than the monocular intermittent condition. At 8-3/4 and 15-3/4 the mean error for both conditions was essentially the same.

Figure 3 depicts the results for observer B. The target distance was nine feet. The pattern is essentially the same as for A (Figure 2). At 8-1/4 the maximum mean error occurred under the monocular intermittent condition. At 15-3/4 the maximum mean error occurred for the binocular intermittent condition, the minimum mean error occurred at 8-3/4. At 8-1/4 and 8-3/4 the monocular intermittent condition showed a greater mean error than the binocular intermittent condition. At 15-1/4 and 15-3/4 this again reversed.

Figure 4 shows the data for observer C. The target distance was 12 feet. The overall pattern of results is similar to that of observer's A and B (Figures 2&3). The mean error for most of the experimental conditions is not significantly different from the binocular steady level. The maximum error under the monocular intermittent condition occurred at 8-1/4, the minimum occurred at 15-3/4. Under the binocular intermittent condition the minimum mean error occurred at 8-3/4, the maximum at 15-1/4. At 8-1/4 and 8-3/4 the monocular intermittent condition exhibited a greater mean error than the binocular intermittent condition. At15-1/4 and 15-3/4 the same reversal pattern is shown for C as for A and B although the difference in mean error is not significant.

Figure 5 illustrates the data for observer D. The target distance was 12 feet. The pattern of results is essentially the same as that obtained for observers A, B and C. The maximum mean error occurred under the monocular intermittent condition at 8-1/4. Under the binocular intermittent condition the minimum mean occurred at 8-3/4 the maximum at 15-1/4. At 8-1/4, 15-1/4 and 15-3/4 the monocular intermittent condition had a greater mean error than the binocular intermittent condition. The mean error as observered for observer C (Figure 4) is not significantly different from the binocular steady level for most of the experimental conditions.

In summary, the main effects to be emphasized are as follows:

1. The maximum mean error for all four observers and all experimental conditions occurred at 8-1/4 under the monocular intermittent condition.

2. Under the binocular intermittent condition, three of the four observers exhibited a maximum mean error at 15-1/4. The maximum for the fourth observer occurred at 15-3/4.

3. For three of the four observers, a reversal is

noted at 15-1/4. For these observers, 8-1/4 and 8-3/4 produced a mean error under the monocular intermittent condition that was greater than the mean error under the binocular intermittent condition. At 15-1/4 and 15-3/4 the mean error resulting from the binocular intermittent condition was greater than the mean error demonstrated under the monocular intermittent condition.

4. All four observers showed essentially the same pattern of results.

Figure 2. Observer A. Target distance nine feet. Mean error($\pm$ S.E.) across all experimental conditions.

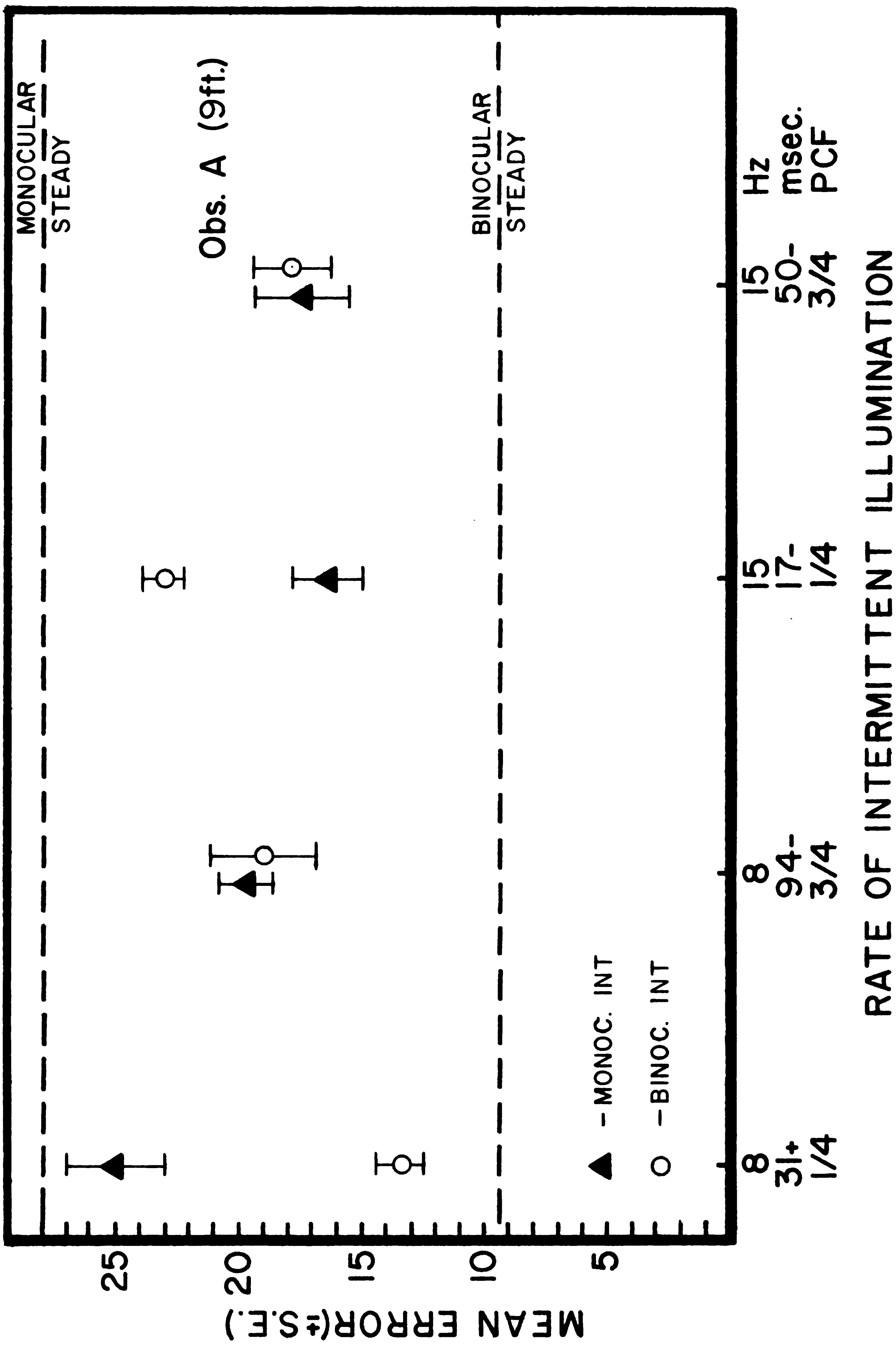

MEAN ERROR(±S.E.)
25
20
15
10
5
MONOCULAR / STEADY
BINOCULAR / STEADY
Obs. A (9ft.)
▲ -MONOC. INT
○ -BINOC. INT
8 31+ 1/4
8 94- 3/4
15 17- 1/4
15 50- 3/4
Hz msec. PCF
RATE OF INTERMITTENT ILLUMINATION

Figure 3. Observer B. Target distance nine feet. Mean error($\pm$ S.E.) across all experimental conditions.

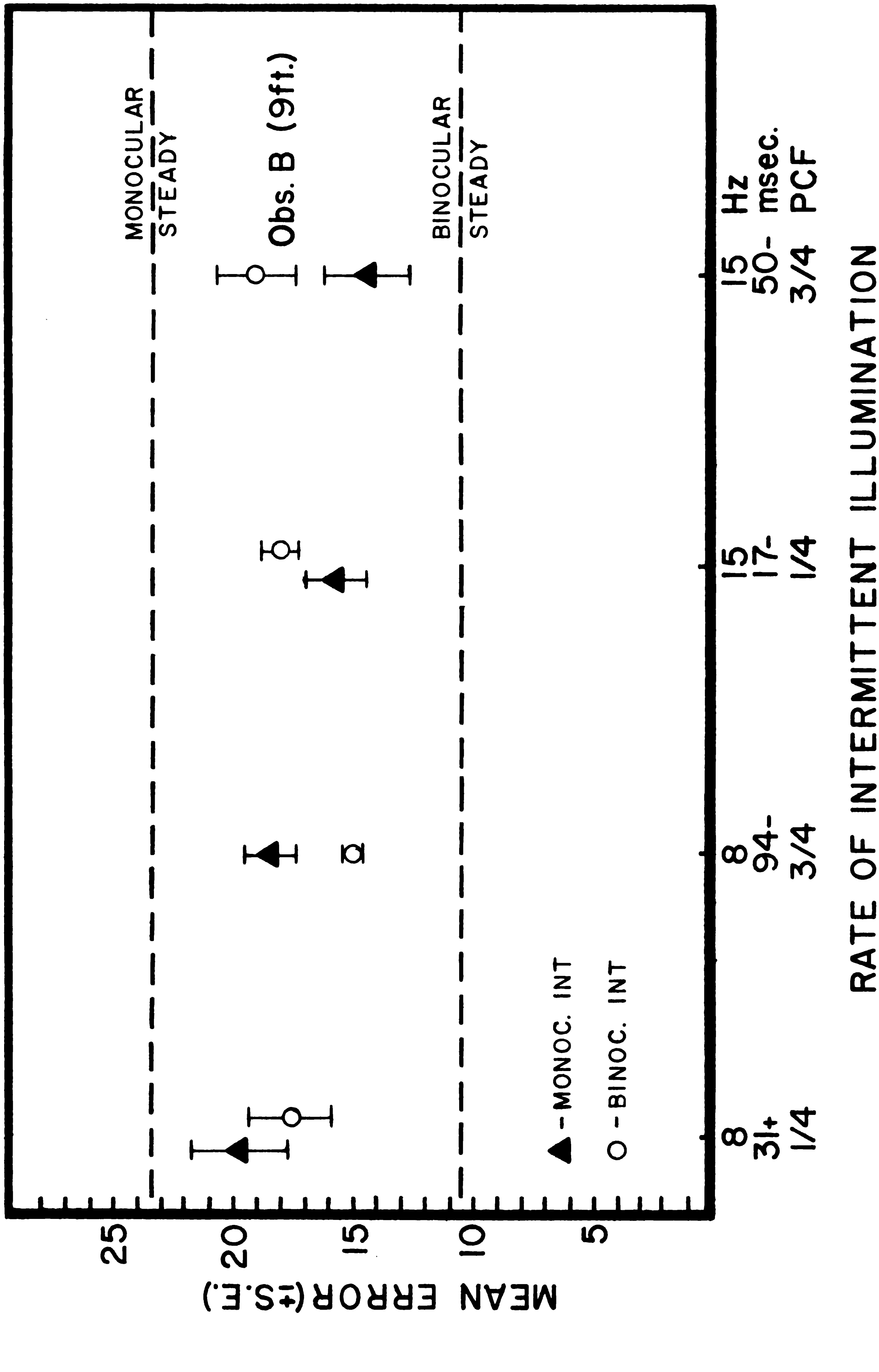
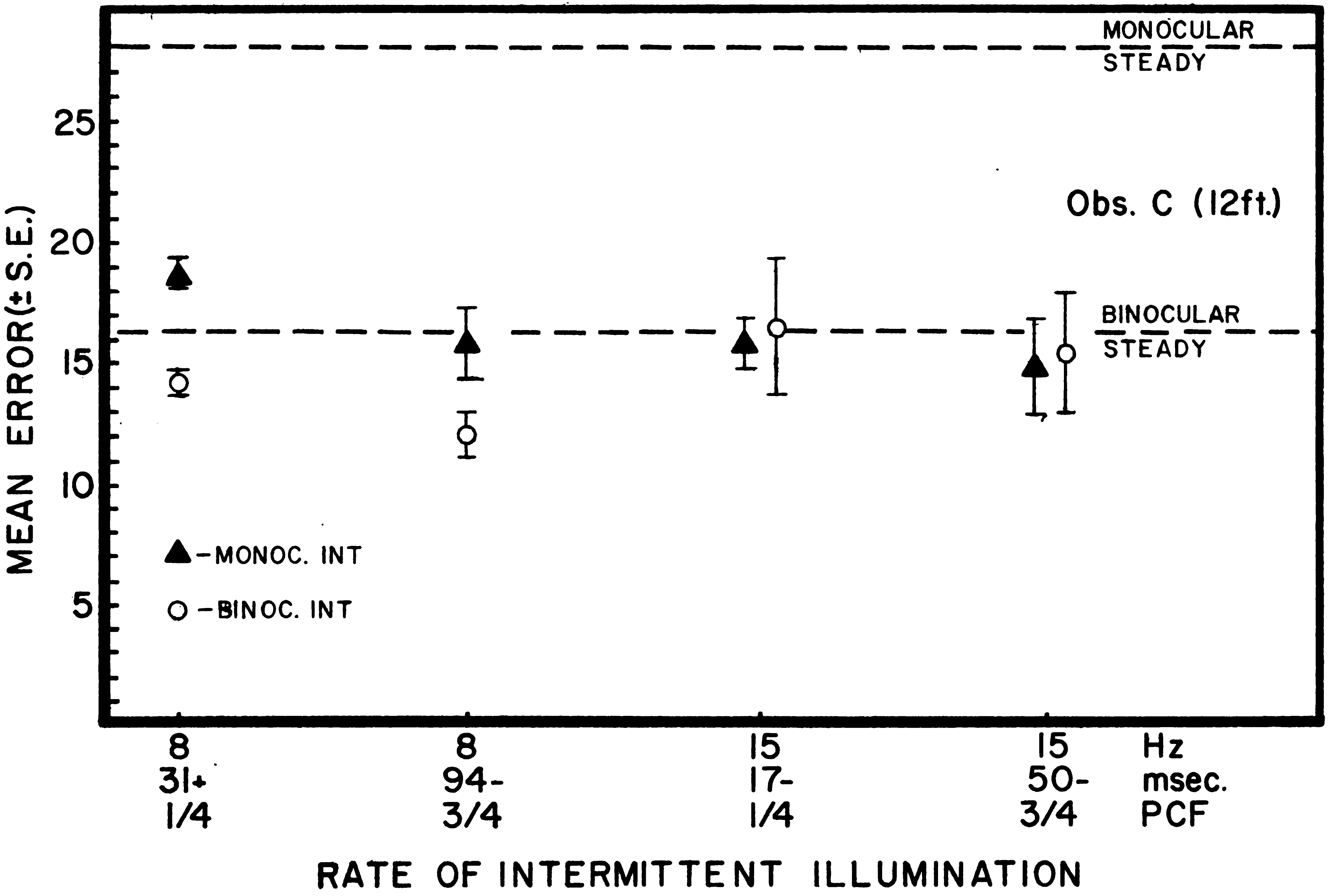
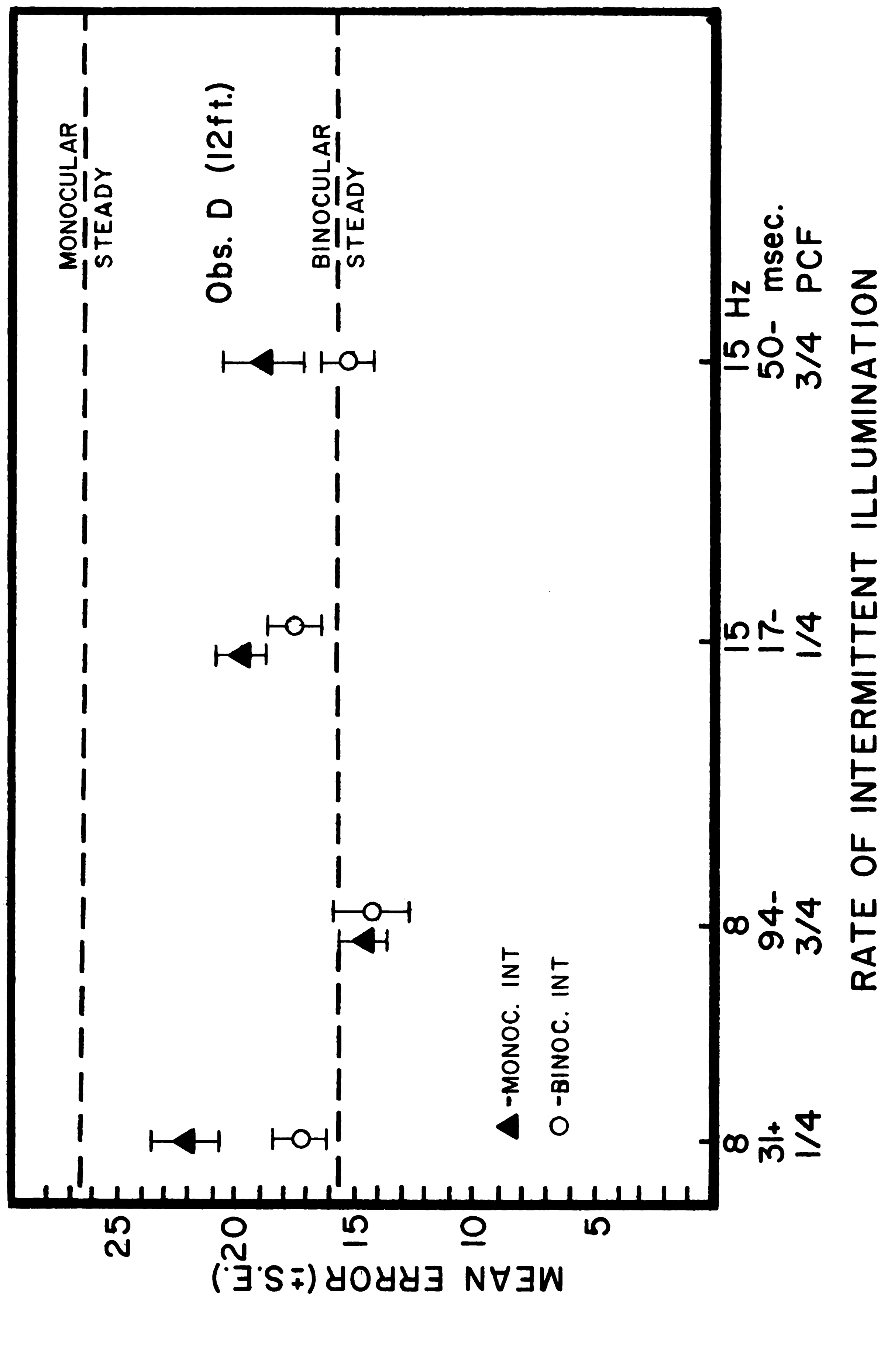

MEAN ERROR(±S.E.)
25
20
15
10
5
MONOCULAR
STEADY
BINOCULAR
STEADY
Obs. B (9ft.)
▲-MONOC. INT
O-BINOC. INT
8
31+
1/4
8
94-
3/4
15
17-
1/4
15
50-
3/4
Hz
msec.
PCF
RATE OF INTERMITTENT ILLUMINATION

Figure 4. Observer C. Target distance 12 feet. Mean error($\pm$ S.E.) across all experimental conditions.



MONOCULAR / STEADY
Obs. C (12ft.)
BINOCULAR / STEADY
▲ -MONOC. INT
○ -BINOC. INT
MEAN ERROR(± S.E.)
25
20
15
10
5
8 31+ 1/4
8 94- 3/4
15 17- 1/4
15 50- 3/4
Hz msec. PCF
RATE OF INTERMITTENT ILLUMINATION

Figure 5. Observer D. Target distance 12 feet. Mean error($\pm$ S.E.) across all experimental conditions.


MONOCULAR / STEADY
Obs. D (12ft.)
BINOCULAR / STEADY
▲-MONOC. INT
○-BINOC. INT
MEAN ERROR (±S.E.)
25
20
15
10
5
8 31+ 1/4
8 94- 3/4
15 17- 1/4
15 Hz 50- msec. 3/4 PCF
RATE OF INTERMITTENT ILLUMINATION

DISCUSSION

Comparing Figures 2 and 3 with Figures 4 and 5, differences are noted between the results obtained at a target distance of nine feet and a target distance of 12 feet. The mean error for all experimental conditions at nine feet was significantly greater than each observer's binocular steady level. For observers C and D at 12 feet, although the pattern of results is essentially the same as A and B's results, many of the experimental conditions showed a mean error that was not significantly different from the observer's binocular steady level.

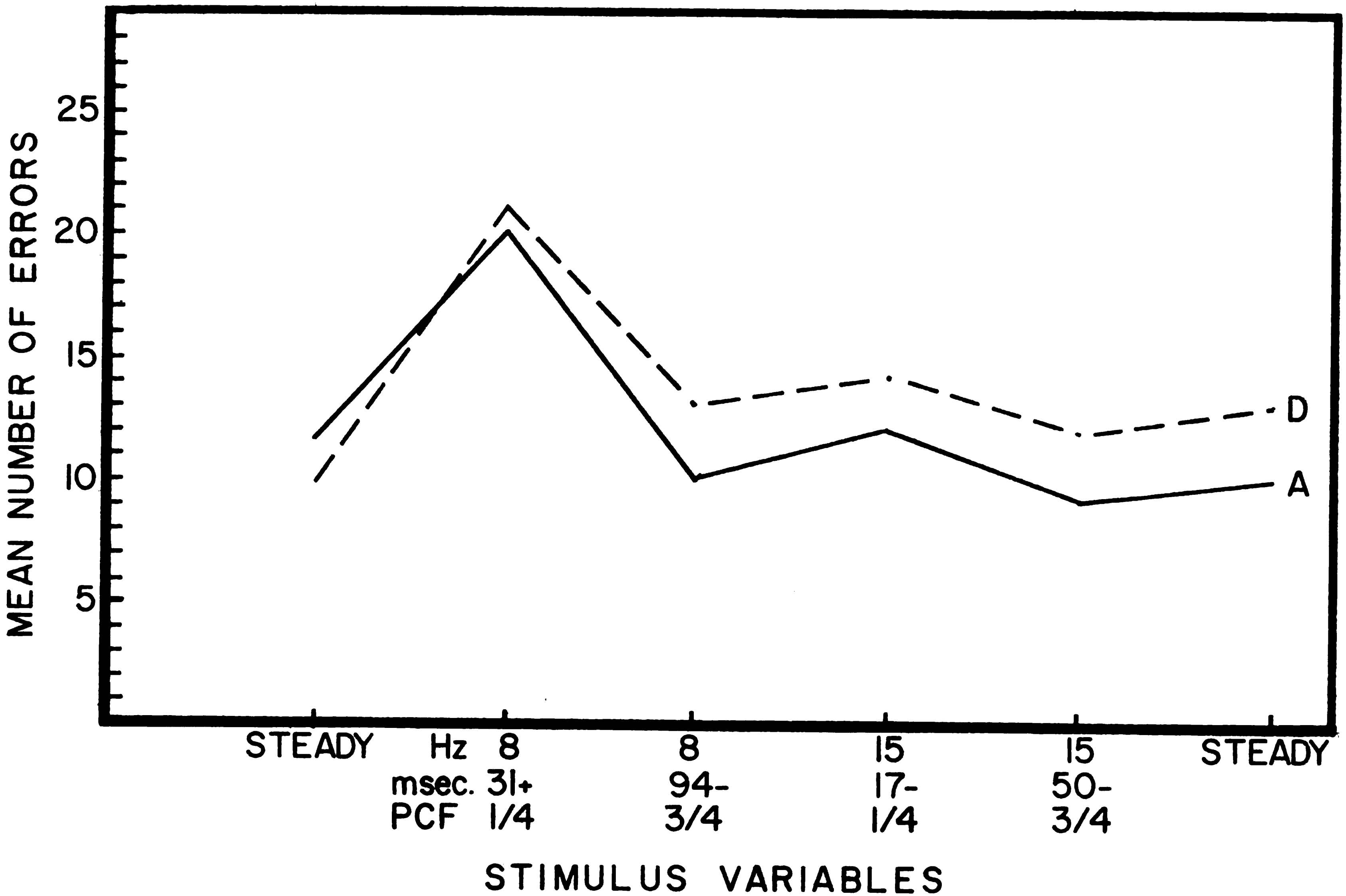
This distance factor may be attributed to the difficulty of the stereoscopic discrimination at 12 feet. The target subtended a visual angle of .0108 at 12 feet. At nine feet the visual angle was .0144 . The entire distance travelled by the sphere was only 3/8" in front of and behind the circular plane. Both observers at 12 feet exhibited a greater mean error for their binocular steady levels than the mean errors shown for observers A and B as their binocular steady levels. As can be seen by comparing the monocular steady levels with the mean errors obtained under the experimental conditions, temporal manipulation does not completely disrupt the stereoscopic process. The maximum impairment obtained under the monocular intermittent condition at 8-1/4 was less than the monocular steady for all observers. Also, the mean error obtained at 8-1/4 was approximately the same for all observers regardless of the target distance involved.

Smolen, Grossman and Bartley(1971) showed a maximum disruption occurring at approximately the same error level as the present study under the monocular intermittent condition. The target distance was six feet. (See Figure 6.) Observers B and C in this study also participated in the earlier study as observers A and D. Thus the collapsing of the mean error level about the observer's binocular steady level might have occurred because of an upper limit on the maximum disruption possible and a higher binocular steady level due to the difficulty of the judgment at 12 feet.

In order to test this hypothesis, further investigation is necessary. Using the same apparatus as the present study, target distance could be advanced from 9 feet to 10, 11, and ... until each observer reached the level at which the binocular steady became chance error(30 errors out of a possible 60). It would be interesting to note whether or not the mean error at 8-1/4 under the monocular intermittent condition would increase. Evidence presented in this study and in the previous one indicate that it might remain constant.

In agreement with Smolen, Grossman and Bartley(1971), the monocular intermittent condition induced a decrement in the stereoscopic process. The maximum impairment, as expected, occurred at 8Hz, PCF 1/4. Thus stereopsis, as visual acuity, color and brightness may be manipulated using the 8-10Hz range. (Nelson, Bartley, Bourassa and Ball; 1971). However, emphasis should be placed upon the effects of the

Figure 6. Reproduced from Smolen, Grossman and Bartley(1971). Mean error across all stimulus variables.


MEAN NUMBER OF ERRORS
25
20
15
10
5
D
A
STEADY
Hz 8
msec. 31+
PCF 1/4
8
94-
3/4
15
17-
1/4
15
50-
3/4
STEADY
STIMULUS VARIABLES

type, not rate of intermittency utilized.

As can be seen from the results, the binocular intermittent condition also caused impoverishment of the stereoscopic process. However, the critical rate of intermittency was not in the 8-10Hz range. For three of the four observers, the maximum mean error occurred at 15-1/4, the fourth at 15-3/4. The import of this result may be shown by comparing the obtained evidence to the visual acuity study. Bartley and Ball(1968) used a binocular intermittent condition to investigate the effects of intermittency on acuity. Intermittent rates of 1,5,10 and 15Hz were used. The maximum decrement occurred at 5Hz, PCF 1/4. The error level dropped considerably at 15Hz, PCF 1/4. In the present study, the reverse was true. The mean error increased from 8-1/4 to 15-1/4 at which point it was maximal.

In conclusion, one must say that although visual acuity and stereopsis may have seemed to involve similar processes, this investigation provides evidence as to their different susceptibilities to temporal manipulation. It appears as though our present ideas relating acuity and stereopsis are in need of revision. If both processes involved similar underlying mechanisms, the effects of temporal manipulation would be expected to be similar.

Further investigation is necessary before a neural explanation of the effect may be suggested. One must take into account the complexities of the binocular system involved in the stereoscopic process. In the following model, Ogle(1959) delineates the neuroanatomic relationships involved:

1) the mosaic structure of the receptor elements of the retinas of the two eyes. At this initial level, stereopsis is assumed to share with visual acuity the contour processes necessary for either the existing disparities or the border-edge discrimination.

2) the pathways of the nerve fibers from the retinas along the optic nerves.

3) the decussation of those fibers so that fibers from homonomous halves of the retinas of the two eyes would pass to the same occipital lobe.

4) the demonstrated close juxtaposition of the fibers from "corresponding" parts of the retinas of the two eyes, even at the level of the lateral geniculate body.

5) the passage of these juxtaposed radiation fibers to the area about the calcarine fissure of the occipital cortex(Brodmann's area 17).

6) the probable dendritic termination of radiations in the area striata of the cortex.

7) the multiplication and overlapping of these termination fibers in those areas.

It appears as though the impairment induced at 8-1/4 under the monocular intermittent condition effects the neural processes of stereopsis in the same manner as visual acuity is affected. This is evidenced by the similarities of both sets of results. However, temporal manipulation using the binocular intermittent condition indicates that other neural disruptions may be involved.

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