STABILIZED RETINAL IMAGES :

THE EFFECT OF CONCURRENT VISUAL STIMULATION

by

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INTRODUCTION

The recent paper by Pritchard, Heron, and Hebb (1960) has provided a review of the current studies of perception using the method of stabilized retinal images. It also gives a mass of seemingly inexplicable information regarding the visibility of the stabilized retinal image.

When a simple line drawing is viewed in the stabilized condition, a remarkable sequence of events takes place. The visual object vanishes, then after a short period reappears intermittently, as a whole or less often in parts. When a complex figure is viewed stabilized, the tendency to break up increases, its parts disappearing independently. The disappearance depends on the complete immobility of the locus of retinal stimulation (i.e. by prevention of "physiological nystagmus"); thus the object can be restored to vision by mechanical destabilization, that is, by moving the contact lens which determines the locus of stimulation. Vision is also maintained much longer when illumination is intermittent (Pritchard, 1958; Pritchard, Heron, and Hebb, 1960).

A theoretically more interesting result from a psychological point of view, however, is the fact that fading is decreased by concurrent stimulation of the other senses. The introduction of a continuous tone or noise results in a higher level of visibility (Pritchard, 1958; Pritchard and Vowles, 1960). A bitter stimulus on the tongue will also restore the figure that has disappeared (Ditchburn, Fender, and Mayne, 1959). These results suggest that the level of arousal is a factor in the maintenance of vision in these conditions.

There is also evidence of an effect of concurrent visual stimulation, which is our present concern. Pritchard, Heron, and Hebb, (1960) report that the duration in vision of one object, and the time of its appearance or disappearance, is affected by the presence of neighboring objects. Two parallel lines, for example, tend to appear and disappear together. The purpose of this thesis is to begin a systematic examination of the effects of concurrent visual stimulation upon the perception of stabilized retinal images.

There is some indication that the structure of the stabilized object itself can determine its visibility; that is, one part of a figure can determine the visibility of other parts of the same figure. This has been noted most frequently in figures which contain parallel lines (Pritchard, Heron, and Hebb, 1960). This seems to indicate the action of field processes, which could result from reciprocal overlap of neural connections as suggested by Marshall and Talbot (1942).

The first set of experiments in this study deals with the effects on a stabilized image of three kinds of concurrent visual conditions: no light, unpatterned light, and patterned light--all presented unstabilized to the contralateral eye. The purpose is to see if an increase in the activity in one eye affects the visibility of a stabilized figure in the other.

In the second set of experiments, stimulation is again presented concurrently to both retinae. One eye views a stabilized straight line; the contralateral eye views a similar line unstabilized. The subject sees these two lines as parallel to each other. The purpose is to examine the effect of the apparent distance between the lines, which can be varied experimentally.

APPARATUS AND PROCEDURE

The subject wears a tight-fitting contact lens on his right eye. A collimating device is carried on the lens which produces parallel light rays (Pritchard, 1960). The image is seen at infinity and therefore is in focus for the normal relaxed eye. The figure viewed is maintained in the focal plane of a high powered glass lens, and is illuminated by a small bulb behind a diffusing screen. The object is seen against a circular patch of light 2 mm. in diameter and giving a visual field of 2^{o}. A shield protects the rest of the eye from stray light. The assembly of the collimator, lens, and target are carried in a ball and socket joint mounted on a Perspex stalk which is fixed to the contact lens. (See fig. 1). The lens fits tightly enough to follow small eye movements accurately (Ratliff and Riggs, 1950; Armington, Ratliff, and Riggs, 1954). Adjustments for aligning the position of the image are allowed by the ball-joint.

The tests were conducted in a lightproof, soundproof room. The subject lay on his back on a couch with his head supported. He was given a highly sensitive micro-switch and was instructed to press it each time the image disappeared, and to release it when the image was again visible. The 18 gram sensitivity of the switch is considerably less than that previously used by Kader (1960), and consequently the act of pressing produces very little somesthetic feedback to interfere with the vanishing of the image. Each time the subject presses, a pen is deflected on a continuously recording kymograph which moves at the rate of one inch every 15 sec. The percentage of each 15 sec. interval that the image is visible may be read directly as hundredths of an inch. This percentage is also known as the stabilized visibility factor or SVF (Pritchard, 1958). The image presented in all conditions was a thin black line of 2' width and 2° length on a white background. In the first experimental condition the left eye was covered so that no light could reach it. In the second experimental condition, the left eye was covered with a half ping-pong ball, which provided a uniform, diffuse white field whose light was of the same intensity as that of the stabilized field in the right eye. The third condition allowed patterned light to reach the uncovered left eye. The subject, thus allowed normal vision in his left eye, was instructed to fixate a spot on the wall of a well lighted room. Fixation reduced the possibility of mechanical destabilization due to voluntary eye movements. Furniture and various pieces of lab. equipment were visible, providing a rich visual input to the unstabilized eye.

There were four additional experimental conditions with the left eye uncovered. An image identical to the one presented in the stabilized condition was projected simultaneously on a screen in front of the subject. The line on the screen was 2 mm. wide and the screen was 8 ft. from the subject's eyes. The resulting image had a 2' arc width on the retina and was equal in length to the stabilized line. The subject looked at the screen with his left eye, while looking at the identical line stabilized in the right eye. There were three fixation points on the screen. The first was 25 mm. to the right of the projected line, the second 75 mm., and the third, 150 mm. The stabilized line in the right eye coincided with the fixation point; when the subject fixated the first point, both lines appeared parallel and close together (25 mm. at 8 ft., or about 30' arc). When he fixated the second point, the lines appeared farther apart (75 mm. or about 80' arc). In the third case, the stabilized line remained in the center of the field while the unstabilized line was seen near the periphery (150 mm. or 160' arc) but still parallel. There was a control condition with a curved line and a series of dots visible on the screen.

At least five separate recordings of each condition were made for each subject. The duration of the testing period ranged from 5 to 30 min. Disappearance of the figure was asymptotic at 5 min. and did not increase or vary much on longer periods of continuous viewing. There was a 10 min. rest period between each trial.

RESULTS

Of the first set of test conditions, dealing with interocular effects, the dark condition gave the least visibility and the most frequent disappearance. After 5 min. of viewing, the image was visible 29.4 per cent of the time, dropping off to 20 per cent after 15 min. Because the major dip occurs in the first 5 minutes, subsequent tests were limited to 5 or 6 minutes. This also increased the accuracy of the readings, as considerable discomfort was felt by the subjects if the sessions were longer.

The diffuse condition gave 53 per cent visibility at the end of 5 min. This is an increase of 20 per cent in the amount of time the image was visible.

The condition where the subject had patterned, unstabilized vision in the left eye gave 73 per cent visibility at the end of 5 min., or a 40 per cent increase over the initial dark condition. See fig. 2.

The second set of test conditions presented the subject with two parallel vertical lines. Figure 3 shows the percentage of time the stabilized figure is visible for each of the three fixation points, as well as the control condition when no parallel line was visible. As the apparent distance between the lines increases, the visibility of the stabilized object decreases. The mean percentages of visibility for the three distances at the end of 5 min. were 71.6 for 25 mm., 66.3 for 75 mm., and 54 for

150 mm. The mean for the control condition was 51 per cent at the end of 5 min. Fig. 4 shows the mean SVF's at the end of 5 min. plotted against the distance between the lines.

The subjects occasionally reported that the fixation points seemed to disappear even though they were not stabilized; this may be due to prolonged fixation. There were also one or two reports that the stabilized line seemed to bend when it was seen near a bending or curved line.

DISCUSSION

The results of the first set of experimental conditions indicate that patterned light on the corresponding part of the contralateral retina maintains visibility of the stopped image better than unpatterned light or no light at all. Patterned activity seems to be important for maintaining the visibility of the stabilized figure. This is in accord with the finding that a varied perceptual environment, rather than a uniform monotonous one, is essential for orderly, stable perception (Heron, Doane & Scott, 1954; Held & White, 1959). The results of the second set of experiments show that the type of pattern presented further determines visibility of the stabilized figure. A duplicate of the stabilized figure, presented in the other eye, is most effective in preserving its visibility. The visibility of the figure is inversely proportional to the apparent distance between the duplicated images.

From this it is possible to infer certain facts about the physiological bases of the phenomena, and about the anatomical structures involved. The data are consistant with the idea that neural activity resulting from presentation of the stabilized figure is facilitated by nearby activity of a similar nature, thus keeping the stabilized object visible. The effect of the unstabilized line on the visibility factor diminishes as the lines are moved apart, therefore the interaction between them may be considered a field effect. A field effect is far more likely to occur in the parts of the afferent visual system which maintain a topological representation of the visual field. These are the retina, the lateral geniculate nucleus, and the visual cortex. Of the three, the retina may be excluded because the stimuli were presented binocularly.

Each line presented is assumed to generate a corresponding neural excitation in area 17 of the cortex. The excitation corresponding to the stabilized line is weaker than that of the unstabilized line. The closer the lines appear together the more overlap there is between their cortical fields. Consequently there is greater neural facilitation by the activity produced by the unstabilized line, and this results in greater visibility for the stabilized one. When the lines are the maximum distance, $2\frac{1}{2}^{o}$ apart, the fields of neural excitation overlap very little, (Clark, 1941). Nevertheless the visibility of the stabilized line is still somewhat more than in the control condition where the unstabilized stimulus was a curved line and a series of dots. Thus, it seems that the similarity of the two stimuli is also a factor in producing greater visibility. Pritchard, Heron and Hebb (1960) found that within a single stabilized image, elementary parts such as single lines tended to disappear and reappear as units. Furthermore, the fact that "meaningful" figures remain visible longer than "meaningless" ones indicates that the facilitating interactions were in terms of meaning rather than purely spatial field effects.

This suggests that neural activity fails first beyond area 17 in the region of divergent and less efficient neural conduction, i.e. the visual association area (Hebb, 1958). There the interaction is no longer facilitated in relation to the spatial separation of the visual objects, but along learned association pathways which connect activities having similar meanings.

While Pritchard, Heron, and Hebb (1960) emphasized the role of meaning in maintaining visibility of a stabilized object, the present study shows that field-distance effects are also important and must be taken into account in an explanatory theory.

SUMMARY

Subjects viewed a stabilized image of a straight line monocularly while various types of visual stimulation were presented to the other eye. In Experiment I these were: 1) darkness, 2) diffuse light, 3) patterned light. Patterned light was most effective in maintaining the visibility of the stabilized image and darkness least effective.

In Experiment II a line parallel to the stabilized line was presented unstabilized in the other eye at three apparent distances from the stabilized line. The visibility of the stabilized line increased as the two lines appeared closer together, indicating a field interaction. The results are explained in terms of neural interaction in the visual cortex.

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Figure 1. Contact lens and collimating system used to produce stabilized images.

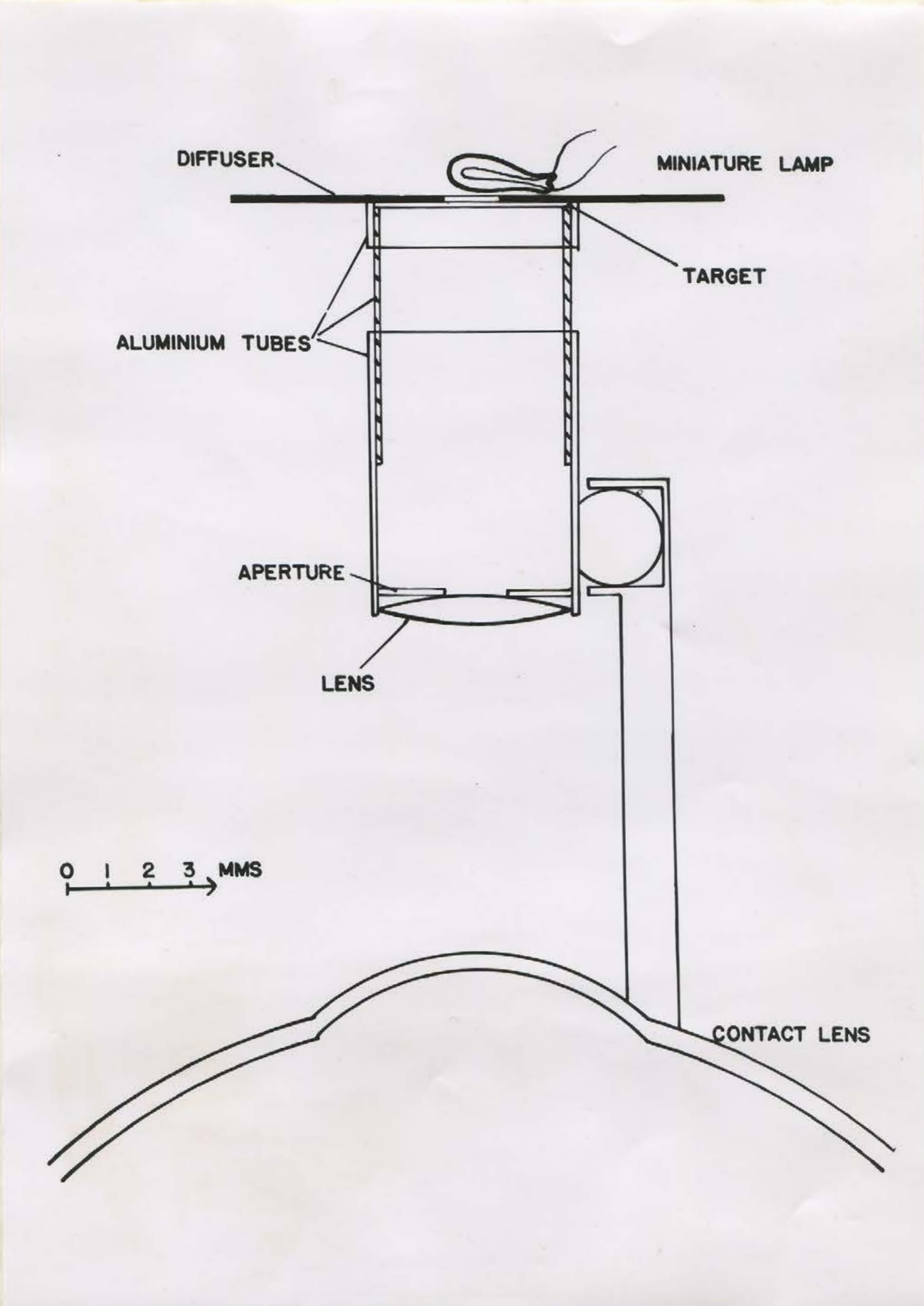

DIFFUSER
MINIATURE LAMP
TARGET
ALUMINIUM TUBES
APERTURE
LENS
0 1 2 3 MMS
CONTACT LENS

Figure 1.

Figure 2. The visibility of the stabilized figure with patterned light, unpatterned light, and no light presented to contralateral eye.

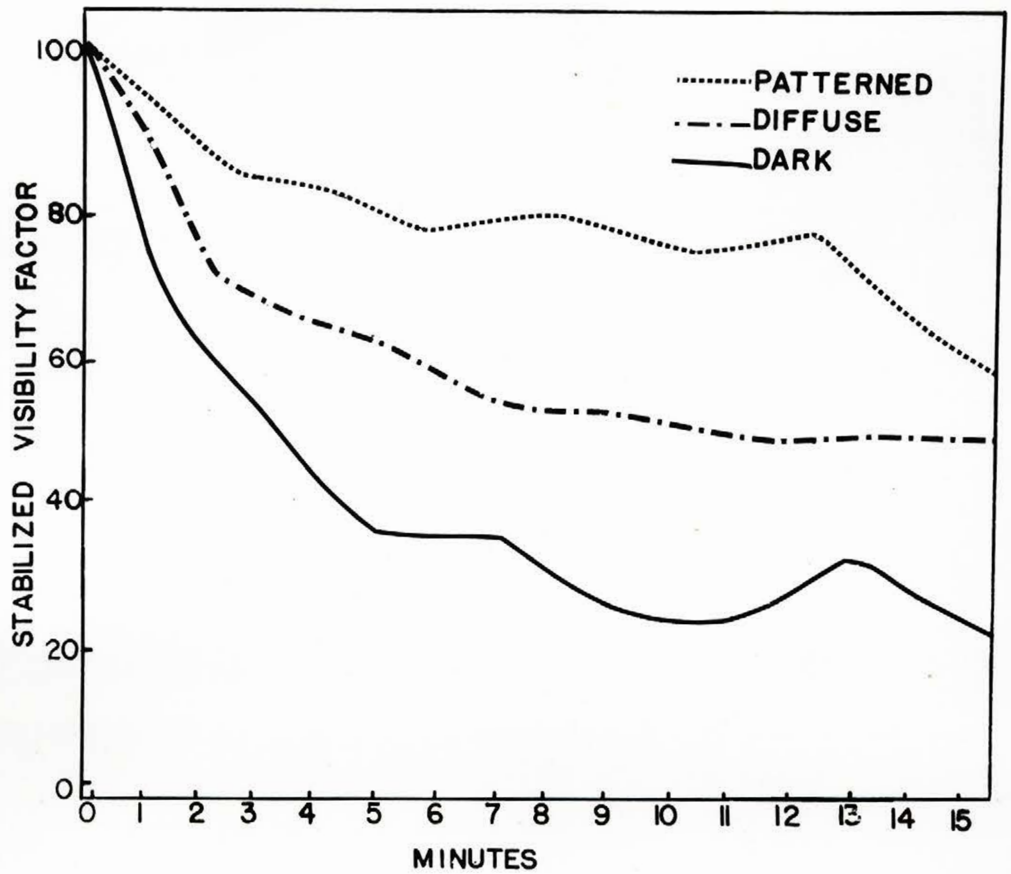
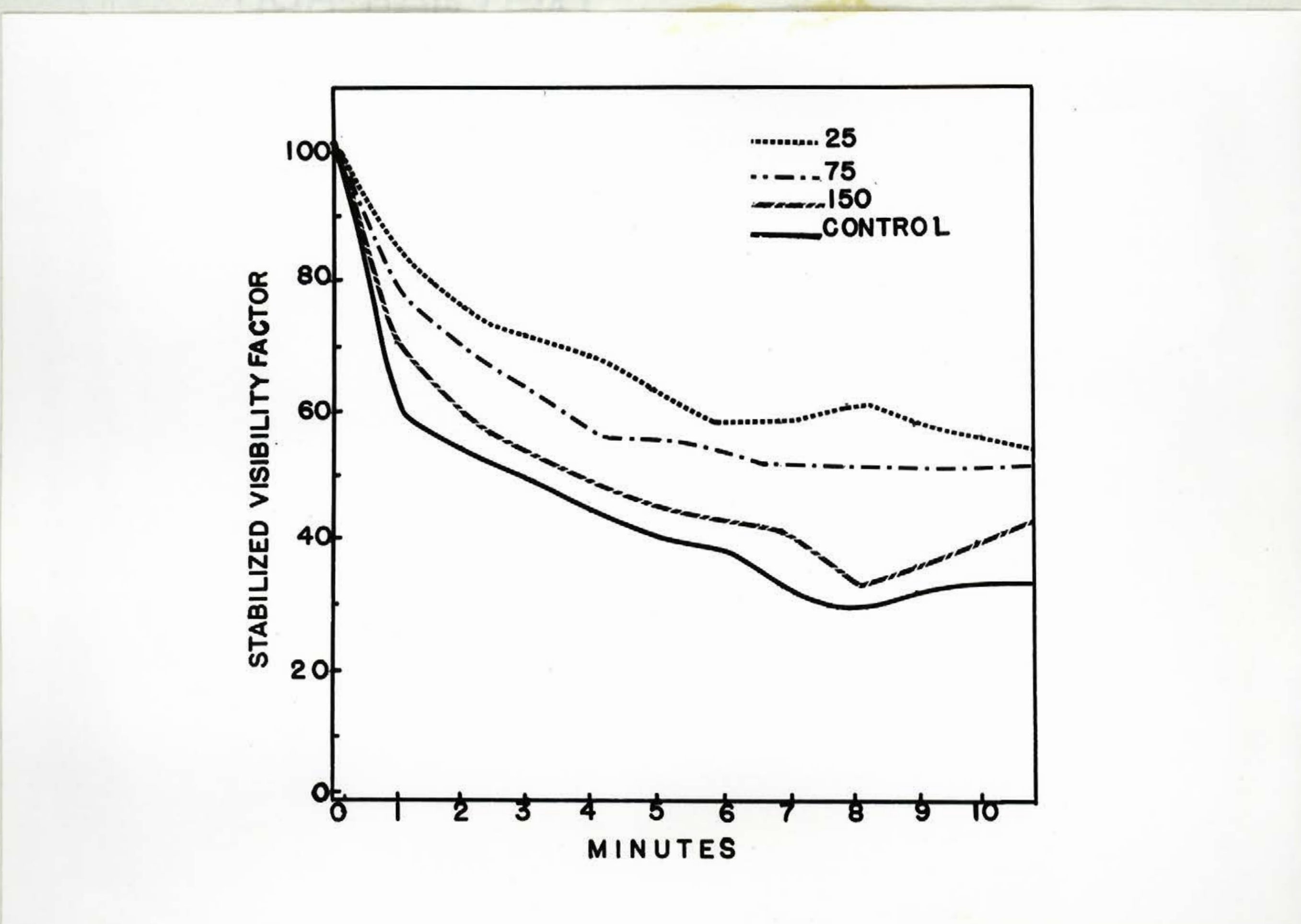

PATTERNED
DIFFUSE
DARK
STABILIZED VISIBILITY FACTOR
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
MINUTES

Figure 2.

Figure 3. The visibility of the stabilized line with second line presented parallel but unstabilized to the contralateral eye at three distances. Control is the visibility of the same stabilized line with no parallel line but pattern of dots and curved line presented unstabilized.



25
75
150
CONTROL
STABILIZED VISIBILITY FACTOR
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
MINUTES

Figure 3.

Figure 4. Decrease in visibility of stabilized line with increase in distance from unstabilized line. Control shows visibility at corresponding fixation points when there is no parallel line present.

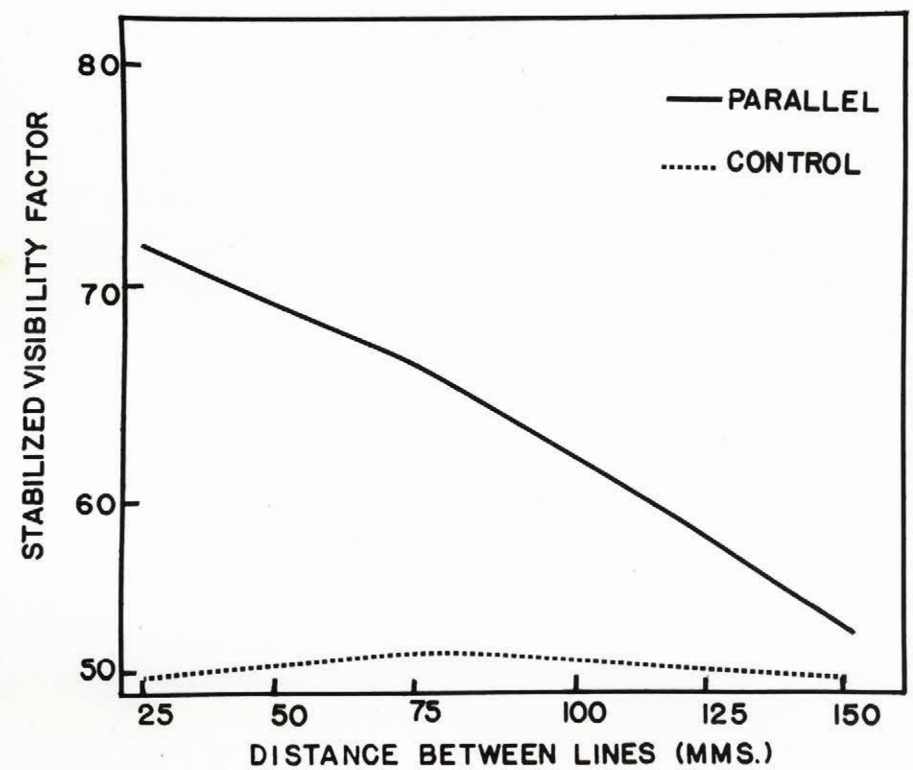

80
70
60
50
PARALLEL
CONTROL
STABILIZED VISIBILITY FACTOR
25
50
75
100
125
150
DISTANCE BETWEEN LINES (MMS.)

Figure 4.