AN INVESTIGATION OF FIGURAL AFTER-EFFECT PHENOMENA: (A) AS A FUNCTION OF RETINAL LOCUS AND (B) THE 'DISTANCE PARADOX'

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ABSTRACT OF THESIS

Although figural after-effect phenomena have been subjected to much experimentation, there are still a number of relatively unexplored aspects and unresolved contradictory experimental results, as well as a need for systematic quantification of the data. The purpose of the present study is two-fold and consists of two experiments. The first is to make a quantitative investigation of the magnitude of the figural after-effect as a function of retinal locus. The purpose of the second experiment is to study the 'distance paradox' phenomenon using single lines as experimental figures, with particular emphasis upon the situation in which these figures coincide under conditions of so-called symmetrical and asymmetrical satiation.

The results of the first experiment demonstrate that the magnitude of the figural after-effect increases as the figures are moved from foveal to peripheral regions on the retina. The second experiment confirms the 'distance paradox' principle and shows that under conditions of so-called symmetrical satiation the 'displacement' phenomenon is not observed when the experimental figures are coincident, but with asymmetrical satiation displacement occurs.

In the discussion of the results the present findings are related to theoretical explanations and investigations of figural after-effect phenomena.

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CHAPTER I

THE PROBLEM AND INTRODUCTION

I. STATEMENT OF THE PROBLEM

Figural after-effects were first reported in 1925 (Verhoeff) and since that time many investigators have studied these phenomena of perception. Even though much attention has been given to figural after-effects, there are still a number of relatively unexplored aspects and unresolved contradictory experimental results. Moreover, even in those areas most thoroughly explored there remains a need for systematic quantification of the data (cf. Osgood, 1953b, p. 241).

This study deals with two problem aspects of figural after-effect phenomena. These are: (a) the relation between retinal locus and the magnitude of the figural after-effect (b) and the 'distance paradox' with particular interest in the situation in which inspection- and test-figures coincide. The use of single straight lines (cf. McEwen, 1958, p. 93) as figures provides the means for systematic quantification.

The relation between retinal locus and the magnitude of the figural after-effect (i.e., displacement of a test-object) has been incidently noted (Gibson, 1933; Köhler and Wallach, 1944) in that it was found to be greater in the periphery than in the foveal area, but there is a lack of systematic exploration.

The 'distance paradox' refers to the magnitude of the figural after-effect as a function of the distance between the inspection- (I-) and the test- (T-) figures. The general nature of the function may be deduced from either of the two competing theories attempting to explain the phenomenon. Both theories, Köhler and Wallach's 'satiation' theory and Osgood and Heyer's statistical theory, predict that no displacement of a test-line is possible when coincident with a single straight inspection-line. With outline, curved or bent line inspection-figures, however, Köhler et al. predict displacement at coincidence (Köhler and Wallach, 1944, p. 351; Köhler and Fishback, 1950a, p. 268), while Osgood and Heyer claim that no displacement occurs (Osgood and Heyer, 1952, p. 106; Osgood, 1953a, p. 212). According to the satiation theory outline figures, such as circles and squares, produce asymmetrical satiation inside as compared to outside the figures which results in the movement of the test-contour coincident with the I-figure. There has, however, been no satisfactory systematic demonstration or quantification of the so-called 'distance paradox', and particularly none that involves the issues of symmetrical and asymmetrical satiation.

The purpose of this study, therefore, is to produce systematic quantitative data in these two relatively unexplored fields.

II. INTRODUCTION

Figural after-effects, in themselves, are not only a matter of interest as perceptual phenomena, but their greatest importance seems to lie in the fact that their investigation is an approach to more basic problems. These phenomena are not merely produced by some unique conditions created in the laboratory, but they may be regarded as examples of processes fundamental to visual, and probably even to other forms of perception. Investigations of figural after-effects, therefore, become a means by which these basic processes may be studied, leading to formulations of theories which can be tested and modified if necessary.

It is hoped that precise and quantitative experiments investigating figural after-effects will lead to a reduction of general laws of seemingly different kinds of phenomena perceived by us through our sense modalities. It was decided that one step in this direction may be taken by investigating a relatively untouched area, and attempting to resolve some earlier conflicting results by exploring a situation in which the satiation and statistical theorists differ in their predictions.

In addition to visual figural after-effects there are also kinaesthetic and auditory after-effects, but these will not be reviewed in this paper.

III. HISTORICAL BACKGROUND

Initial Reports

Although Verhoeff (1925) was the first to report a figural after-effect, credit for its discovery must be given to Gibson (1933). Gibson found that when a person wore spectacles containing prisms which curved the visual field by 15 degrees, the visual field appeared less curved after a period of time. When the prisms were removed the subject reported that the field was curved in the opposite direction to that produced by the spectacles. He called the decreasing curvature while wearing the prisms 'adaptation', and the distortion following removal of the spectacles, the 'after-effect' (Köhler and Wallach, 1944, called the latter phenomenon a figural after-effect). Gibson later found that the same phenomena were observable when a curved line was inspected and subsequently replaced by a straight line.

Gibson (1937) and Gibson and Radner (1937) continued to study these phenomena and among other things concluded that with curved or bent lines the adaptation and after-effect were the result of continued inspection of a line, the crucial characteristic of which was its curvature or bending. A straight line was a "norm" and deviations from it with prolonged inspection resulted in adaptive processes. Tilted lines also displayed adaptation and after-effect since they deviated from the vertical and horizontal which were regarded as norms or standards.

Gibson's 'curved line effect' was confirmed by Bales and Follansbee (1935), and Vernon (1934) provided supportive evidence for the 'tilted line effect', but differed from Gibson in the explanation of her results.

Most of Gibson's findings have since been confirmed, but his explanations have not been accepted. Gibson assumed that figural after-effects were produced by deviations of inspection-objects from "norms". Köhler and Wallach (1944) argued that figural after-effects were not restricted to such special conditions. They showed that these phenomena could be observed by using an inspection-line which did not deviate from the horizontal norm. According to Gibson no tilted line effect should be produced in such a situation. Köhler and Wallach contended that inspection of any object could produce figural after-effects, and that Gibson's results may be interpreted in terms of the theory which they propose.

Conditions and Theories

In 1944 Köhler and Wallach published qualitative and quantitative evidence regarding the phenomena of figural after-effects, and proposed a theory attempting to account for their results and those of earlier investigators. Osgood and Heyer (1952) who disagreed with this theory, postulated their own which they believed to be more in line with contemporary neurophysiological principles. Before these theories are briefly outlined it might be well to explain what Köhler meant by the phenomena which he named figural after-effects.

There follows a description of the conditions under which the phenomena occur, an outline of the two theories attempting to account for them, and then a discussion of the nature of the phenomena.

It is important to note that throughout the series of observations described below the subject maintains a constant fixation point. A head rest is used to minimize head movement and instructions are given to assume, as far as possible, the constancy of fixation. As a control test the subject is usually presented with two identical figures (T-figures) symmetrically placed on either side of the fixation point. He reports differences, if any, between the figures (none is expected).

After a rest period of approximately one minute, an inspection-figure, usually single, is presented on one side of the fixation-point (it is important that the I-figure bears the proper spatial relationship to the T-figure). This is observed for a period of time. The subject then briefly closes his eyes while the test-figures are presented. He is asked again to report differences, if any, between the two figures. Observed differences are called figural after-effects. The test-figure on the side of the previous inspection-figure is usually affected and may appear paler, smaller, further back, or displaced in relation to its unaffected partner.

The Köhler and Wallach theory of figural after-effects is an extension of Köhler's earlier speculations (1920, 1929, 1938, 1940) regarding mainly the explanation of perceptual data in terms of an electrical field theory. According to this theory some part of the central visual system must be regarded as a kind of homogeneous volume of tissue which is capable of carrying electrical currents. It is assumed that these currents flow in areas of least resistance. The very flow of this current through these tissues polarizes the membranes and thus increases the resistance to the flow of subsequent electrical currents. The presence of the inspection-figure causes a flow of current in the central visual system along the contours of this figure. This flow of current gradually increases the electrical resistance of the tissues through which it passes, forcing the current to flow into neighboring areas, thus establishing a gradient of increased resistance, or as Köhler called it, 'satiation', around the inspection-contour. Since this condition of satiation persists for a period of time, its effect may be observed by introducing a test-contour falling within this satiated region, and measuring its distortion. In other words, the flow of current constituting the affected test-contour is weaker than its unaffected partner and is deflected from the heavily satiated areas which accounts for the observed changes in brightness, size, distance from observer and location of the test-figure.

Osgood and Heyer (1952) being of the opinion that figural after-effects can be explained in terms of more generally accepted neurophysiological principles, propose an alternative theory called the statistical theory. On the basis of work done by Marshall and Talbot (1942) Osgood and Heyer assume that "the representation of a contour in the projection cortex (area 17) is a normal distribution of excitation, symmetrical about its axis transversely and extending as a 'ridge' throughout the longitudinal extent of the contour" (1952, p. 102). This distribution of excitation is produced by physiological nystagmus, reciprocal overlap of dendritic processes, and is dependent upon vertical summation. Osgood and Heyer also assume that 'on-off' receptor processes in the retina are chiefly involved in contour formation. With prolonged fixation of a figure, gradients and peaks are established, and the cells mediating the 'on-off' activity become differentially adapted by the rate and length of time of their excitation. They also assume that "the apparent localization of a contour in subjective visual space coincides with the location of maximal excitation in area 17" (1952, p. 104).

Osgood and Heyer (1952) believe that their theory can account for all the phenomena explained by Köhler and Wallach's theory. They claim, however, that their statistical theory does not disprove the satiation theory, but state that whereas the Köhler-Wallach theory postulates novel, non-neural electrical currents in the brain, their theory is founded upon contemporary neurophysiological principles.

Nature of Figural After-Effects

Köhler and Wallach (1944) reported that figural after-effects have a number of characteristics: the affected test-figure may appear paler, smaller, further back, or displaced in space as compared with its unaffected partner. These characteristics along with some pertinent investigations will now be discussed.

One of the characteristics of figural after-effects is the fading of the affected test-figure. Koffka (1935) predicted that the threshold of a variable figure was probably higher inside a closed contour figure than outside the contour. He based this prediction partly on the results of Gelb and Granit's (1923) and Granit's (1924) experiments which were concerned with differences in threshold on figure and ground. Craik and Zangwill (1939) found that the threshold of a small figure of variable brightness was significantly higher inside a closed figure than outside the contour, thus confirming Koffka's prediction.

According to Köhler and Wallach's satiation theory differential thresholds of test-figures falling inside and outside a previously inspected outline figure should be observed. Also, the threshold is a function of the distance between the I- and T-figures, that is, the threshold is highest at the inspection-contour and decreases as the distance from the I-figure increases. Bevan (1951) tested these predictions and found that the thresholds of T-figures inside an I-figure were higher than those outside the figure. He also confirmed Köhler and Wallach's prediction by showing that the threshold varied with the distance between inspection- and test-figures.

After it had been shown that the affected test-figure appears further back in space than its unaffected partner following the inspection of the I-pattern, Köhler and Emery (1947) went on to show that figural after-effects occur in the third dimension. They found that the inspection of an object tilted from the frontal plane resulted in a displacement of the T-object in the third dimension. They claimed that such after-effects were similar in a number of ways to those in the frontal plane.

Köhler and Emery, who used relatively untextured surfaces, emphasized the importance of the perception of the edges of the objects they used as the determiners of their depth effect. Bergman and Gibson (1959), however, demonstrated after-effects of slanted surfaces when no edges were involved. The latter investigators concluded that such visual after-effects could not be included under figural after-effects.

Köhler and Wallach demonstrated the nature of figural after-effects using various figures. One figure which supports their theory and has been used by many investigators is their Figure 5. In this arrangement the inspection-pattern is a dark outline circle drawn above a fixation point on a white background. The test-figure consists of two equal outline squares symmetrically placed above and below a fixation mark with the upper square lying completely within the area of the inspection-figure.

Since the upper square lies within a satiated area it will appear paler, smaller, further away and displaced in relation to the lower square. According to the satiation theory the interior of the I-circle will be satiated. Since the condition of satiation is still present when the T-pattern is shown, the figure-currents produced by this figure will develop, but the upper figure-current will be developing in a satiated region while the lower one will be in a relatively unsatiated area. As a result the upper figure-current will be weaker than the lower since it will be developing in an area having a higher resistance to the flow of current, and will also turn away from the more satiated area which in this case will be toward its own interior. The upper square will therefore appear paler, smaller, further away and displaced in relation to the lower square.

Hebb (1949) disagrees with Köhler and Wallach and states that the upper square should appear larger than the lower one. Since the upper figure lies in a satiated area, he argues that according to the satiation theory there will be an increase in resistance to currents from opposite sides of this figure which should make it appear larger than its unaffected partner.

It seems that Osgood and Heyer can account for the observed changes of the affected T-figure in terms of their theory in the following way. Since the T-contour falls inside the I-figure the symmetrical distribution of excitation that the T-square would normally produce is changed by the differential excitability of the cells in this area. The locus of maximal excitation, therefore, is shifted, which in this case gives the appearance of shrinkage. Since contrast is dependent upon the amplitude of excitation at the contour which in this case is reduced in the region of adaptation, the top square will appear paler than the bottom square. If the subject is set to make judgments of distance, the reduced size is interpreted as a change in distance.

Using Köhler and Wallach's Figure 5, Walthall (1946) confirmed the original results but found that without prior fixation of the inspection-figure the lower square appeared larger. He suggested that cumulative effects of the earlier trials might explain this, but Weitz and Post (1948) obtained similar results under conditions where such effects could not be operative.

Marks (1949a) varied the pattern of Köhler and Wallach's Figure 5 and found, like Weitz and Post, that indications of satiation were reported a significant number of times under conditions in which there was no satiation, that is, when no I-figure was used. On the basis of this study and a later investigation (1949b) Marks concluded that the observed phenomena were incompatible with and not predictable from the satiation theory.

Weitz and Compton (1950), using varied forms of Köhler and Wallach's Figure 5, reported numerous observations that were opposite to and not predictable from the satiation theory. Using a variation of Figure 5, George (1953), on the other hand, found that his subjects observed the predicted effects.

A possible source of disagreement among the reported results may be due to differences in apparent size on opposite sides of a visual meridian without prior inspection which Brown (1953) has called Half-Meridional Differences (HMD's). Brown found that these HMD's varied in size and direction among subjects and could distort results in figural after-effect experiments if they were not taken into consideration.

Köhler and Wallach (1944) reported that when single I- and T-lines coincide, there should be no spatial displacement of the T-contour, although it may appear paler than an unaffected figure. As the distance between the inspection- and test-lines is gradually increased, the displacement of the latter increases and passes through a maximum, and then decreases again to zero. This phenomenon Köhler and Wallach called the 'distance paradox'. Both the satiation and statistical theories claim to account for it.

It should be noted that in the above situation in which straight lines are used, Köhler and Wallach's and Osgood and Heyer's theories predict that no displacement will occur when the I- and T-contours are coincident. When outline figures such as circles or oblongs are used as I-patterns, however, from the satiation theory, Köhler et al. predict displacement of the affected T-figure when coincident with the I-figure, while the statistical theorists claim that no displacement occurs.

According to Köhler and Wallach's theory when single I- and T-lines are used the pattern of satiation is symmetrical on both sides of the I- and T-lines and, therefore, the T-contour cannot be displaced when it coincides with the I-figure (1944, p. 351). When the I- and T-contours are curved or have angles, then satiation will not be the same on both sides (inside and outside) of these figures. Köhler and Wallach state that "...a circle satiates its interior more strongly than its environment..." (1944, p. 351). Referring to the angles in the Müller-Lyer illusion Köhler and Fishback (1950a, p. 269) claim that repeated presentations or inspection of these figures causes a higher level of satiation inside these angles than outside of them. Due to this condition of asymmetrical satiation the authors state that "...the angles must be displaced into the less satiated regions, i.e., in the direction of their apexes" (p. 268).

Osgood and Heyer (1952) and Osgood (1953a), assuming that reported displacements at coincidence with outline figures may be explained by paleness cues, predict that no displacement can occur at coincidence. Referring to an arrangement in which I- and T-oblong figures are used, Osgood and Heyer state that "...if the contour of the T-figure precisely coincides with that of the previous I-figure, no displacement occurs whatsoever..." (1952, p. 106).

Walthall (1949), using circles as I- and T-figures, found that the magnitude of the after-effect varied as a function of the distance between inspection- and test-figures. That is, the closer the T-circles were to the I-circle, the more they were compressed.

In 1951 Fox carried out two quantitative experiments testing Köhler and Wallach's 'distance paradox' principle. In his first experiment Fox verified the 'distance paradox' except for the condition in which the T-dots coincided with the I-figure which consisted of a rectangle. In this arrangement the test-dots were displaced. Reasoning that an uncontrolled factor, adaptation (Gibson, 1933, 1937; Gibson and Radner, 1937; Prentice and Beardslee, 1950), may have produced displacement at coincidence, Fox carried out a second experiment in which this factor was eliminated. Using solid black rectangles as I-figures and dots as T-objects, the 'distance paradox' was confirmed. Unlike the first experiment, no significant displacement was recorded at coincidence.

It should be noted that although Fox used a method of quantification, his inspection-figures were rectangles, which according to Köhler et al. (1944, 1950a) produce a pattern of asymmetrical satiation. Consequently, it seems that Fox (1951, p. 322, 324) is incorrect in assuming that according to Köhler and Wallach's theory the T-dots should not be displaced when coincident with the I-contours.

Ikeda (1951), Ikeda and Obonai (1955), Kogiso (unpubl.) and Oyama (1954) measured the growth and shrinkage of a T-circle by varying the size of the I-circle from smaller to larger than the T-figure. Oyama (1956b) discussed the results and stated that the 'displacement' principle was confirmed, that is, the T-circle expanded when the I-circle was smaller and shrunk when the I-circle was larger. Again the 'distance paradox' was verified, and when the test-circle coincided with the inspection-circle, these investigators found that the T-circle shrunk. Oyama (1956b) regarded the displacement at coincidence as being contrary to Köhler and Wallach's theory. It was also found that the point of optimal displacement was not dependent upon an absolute distance between the I- and T-circles, but upon their relative sizes. That is, maximal growth occurred when the I-circle was one-half the diameter of the T-circle, and maximal shrinkage was recorded when the I-circle was twice the size of the T-circle.

The criticism that was made regarding Fox's assumption applies also to Oyama's interpretation of Köhler and Wallach's theory. That is, according to Oyama's interpretation of the satiation theory, the T-circle should not be displaced when it is coincident with the I-circle. As was mentioned earlier, Köhler et al. (1944, 1950a) claim that no displacement at coincidence occurs only when single I- and T-lines are used. With these figures satiation is symmetrically distributed and therefore the T-line will not be displaced when it coincides with the I-line. When curved contours, or those having angles, are used, the pattern of satiation inside and outside the figures is asymmetrical, therefore, displacement at coincidence will occur. Osgood and Heyer (1952) and Osgood (1953a), as was stated earlier, predict no displacement at coincidence. It seems that there is here a situation in which the theorists differ and which can be experimentally tested.

As was mentioned earlier, Hebb (1949, pp. 54-58) criticizes Köhler and Wallach's satiation theory because it does not seem to fit all the empirical data. One important criticism which Hebb makes is the situation in which a test-figure coincides with an inspection-square or circle. Hebb claims that according to the satiation theory the coincident T-square or circle should increase in size, since there is increased resistance to the flow of current between the opposite sides of this T-figure. This should result in an overestimation of the size of the affected T-figure.[1] He points out that Köhler and Wallach report the opposite, that is, the affected test-figure shrinks as compared to its unaffected partner. It should be noted, too, that the above mentioned investigations of the 'distance paradox'

[1] The direction of the displacement at coincidence is dealt with in the Discussion, Chapter III

show the same direction of displacement.

Factors Affecting Figural After-Effects

Since the time of the discovery of figural after-effects investigators have been concerned with the effect of various factors on these phenomena. Studies dealing with the effect of such variables as color and brightness, temporal aspects, solid vs. outline figures, retinal size and apparent size of the stimulus, metabolic efficiency and retinal locus have been reported. Since only the factor of retinal locus is involved in this study, a brief historical review of the relation between the magnitude of the figural after-effect and retinal location shall now be outlined.

The effect of retinal locus on the magnitude of figural after-effects has been mentioned by a number of investigators. Gibson (1933) reported that the after-effect was larger when the inspection-figure was exposed peripherally than foveally. Köhler and Wallach (1944) also realized this and claimed that satiation spread further in peripheral than in parafoveal areas. They also stated that "...when objects are projected upon the periphery of the retina their images have not quite the same size as they have nearer the fovea" (1944, p. 346).

On the basis of a few observations Köhler and Wallach reported that the distance at which maximal displacement took place was greater when both the inspection- and test-figures were in the periphery than near the fovea. Other than this no quantitative and systematic study on the magnitude of figural after-effects as a function of retinal locus seems to have been reported.

Critique of Previous Investigations

The preceding review has shown that there are a number of relatively unexplored aspects and unresolved contradictory experimental results of figural after-effect phenomena. Also, most of the studies which have been reviewed did not employ systematic and quantitative methods which are very much needed in this field of research (See McEwen, 1958, p. 46; Osgood, 1953b, p. 241).

The first objective of the present study is to investigate the magnitude of the figural after-effect as a function of retinal locus. As was mentioned earlier, the influence of retinal location was incidently mentioned (Gibson, 1933; Köhler and Wallach, 1944), but no quantitative study seems to have been reported. It was therefore decided to study systematically and quantitatively the magnitude of the displacement of T-lines as a function of retinal locus.

Although the 'distance paradox' principle is predicted by the two theories attempting to explain figural after-effect phenomena, only outline figures such as rectangles and circles have been used to study it. As was mentioned earlier, such figures raise the question of asymmetrical satiation which, according to Köhler et al.

(1944, 1950a), should result in a displacement of the T-contour coincident with the I-figure. Osgood and Heyer (1952) and Osgood (1953a), as was noted, assume that reported displacements at coincidence with outline figures may be explained by paling of contours, and predict that no displacement occurs at coincidence. The purpose of the second part of this study, therefore, is to make a quantitative study of the 'distance paradox' using a single line as I- and T-figures, and to investigate the after-effect, if any, at coincidence under conditions of so-called symmetrical and asymmetrical satiation, using a method in which the paling of contours will not affect the results.

CHAPTER II

EXPERIMENT I: METHOD, RESULTS AND DISCUSSION

The Problem

The preceding chapter has shown that the relation of retinal locus to figural after-effect phenomena has been only incidently noted, but never thoroughly studied. The purpose of Experiment I, therefore, is to make a quantitative investigation of the magnitude of the figural after-effect as a function of retinal locus.

Apparatus

A diagram of the I- and T-figures (lines E and V) and the positions of the fixation points are shown in Figure 1. Lines E and V are 3" long and .025" wide and drawn in black india ink on two round white cardboard disks 3" in diameter. These two disks are horizontally placed ½" apart against a thick white 30½ X 40" cardboard plate. Mid-way between and in the same horizontal plane as the centers of these two disks is a fixation point X which is drawn on the cardboard plate. From this central fixation point (X) all other fixation points are drawn 2" apart in the vertical, horizontal and oblique positions on the cardboard plate, except for points A and F which are approximately 3" from X, and K and P which are approximately 3½" from X.

All the fixation points are divided into six groups with six points in each group. Group 1, in which the I- and T-figures fall in the upper nasal and temporal retina, includes fixation points X,1,2,3,4,5; Group 2, upper temporal, X,F,G,H,I,J; Group 3, lower temporal, X,P,Q,R,S,T; Group 4, lower nasal-temporal, X,6,7,8,9,10; Group 5, lower nasal, X,A,B,C,D,E; Group 6, upper nasal, X,K,L,M,N,O.

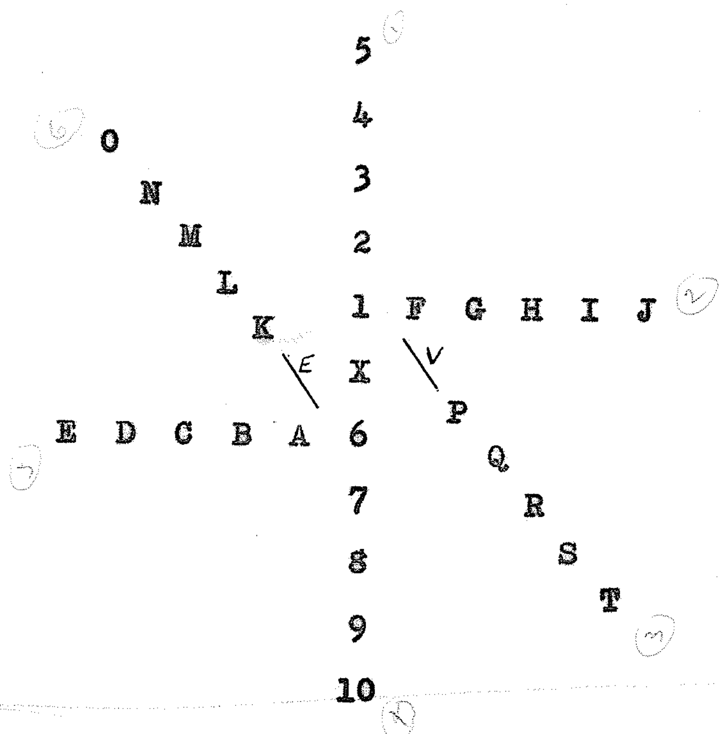

Figure 1 Diagram of Inspection- and Test-figures (lines E and V) and Fixation Points

The apparatus consists of a wooden frame 27 X 30" to which the $30\frac{1}{2}$ X 40" cardboard plate is fastened. Directly in front and in the center of this cardboard plate are the two above mentioned disks carrying lines E and V. The disk to the left of fixation point X can be rotated by the experimenter and is connected to a pointer on a compass behind the apparatus. The disk to the right of fixation point X is attached to a pointer on another compass and to a number of gears to which a rod is connected which can be turned by the subject, thus changing the tilt of line V. All compass readings are accurate to 0.25 degrees. A moveable shield to cover line V is attached to the apparatus, and a head-rest, fitted with a shield to cover the subject's right eye, is located 24" in front of lines E and V. The apparatus was placed on a table so that fixation point X is at the eye-level of the subject.

Procedure

The right eye of each subject was covered so that vision in this experiment was restricted to the left eye. Before the experiment was begun the subject was given a practise period. The subject was required to keep his eye on the fixation point designated by the experimenter, and turn the variable line (V) until it appeared parallel to line E which was tilted 45 degrees from the vertical. Having made an adjustment, the shield was immediately moved to cover line V, and the subject was told to rest his eyes for approximately 20 sec. Before the subject made each adjustment line V was set at varying points around the vertical.[2] After the subject had familiarized himself with his task, and was able to do it quite accurately and within 7 to 10 sec., the practise period was terminated.

One group of fixation points was used in each session,

[2]In a preliminary study it was found that when line V was turned in this general direction before the subject made an adjustment, results were most reliable

and sessions were separated by approximately a day. The fixation points in each group as well as the groups themselves were presented in counterbalanced order so that all the possible positions in a series was given.

Following the practise period the subject was given a 2-min. rest. A predetermined group of fixation points and order of presentation for each point was then selected and the subject was asked to put his head in the head-rest, keep his eye on the fixation point designated, and turn line V until both lines (E and V) appeared parallel. Six such control readings using each of the six fixation points in a group were taken with a 20 sec. rest period between each.

Following these control adjustments the subject was given a 2-min. rest and told that he would shortly be required to keep his eyes on a designated fixation point for a period of time, after which both lines would be moved into different positions, and while looking at the fixation point make both lines parallel as he had done before. Line E was then set at 55 degrees from the vertical, and line V at 35 degrees. This setting of the lines constituted the inspection-figures.[3] The shield was then removed and the subject was asked to look at one of the fixation points for 60 sec., after which line E was immediately returned

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[3] On the basis of experiments by Gibson and Radner (1937) and Köhler and Wallach (1944, pp. 310-311), the I- and T-figures were separated by 10 degrees and placed in the neighborhood of 45 degrees. Also, two I-figures were used to give maximum results (See Köhler and Wallach, 1944, pp. 305-306, Fig. 55)

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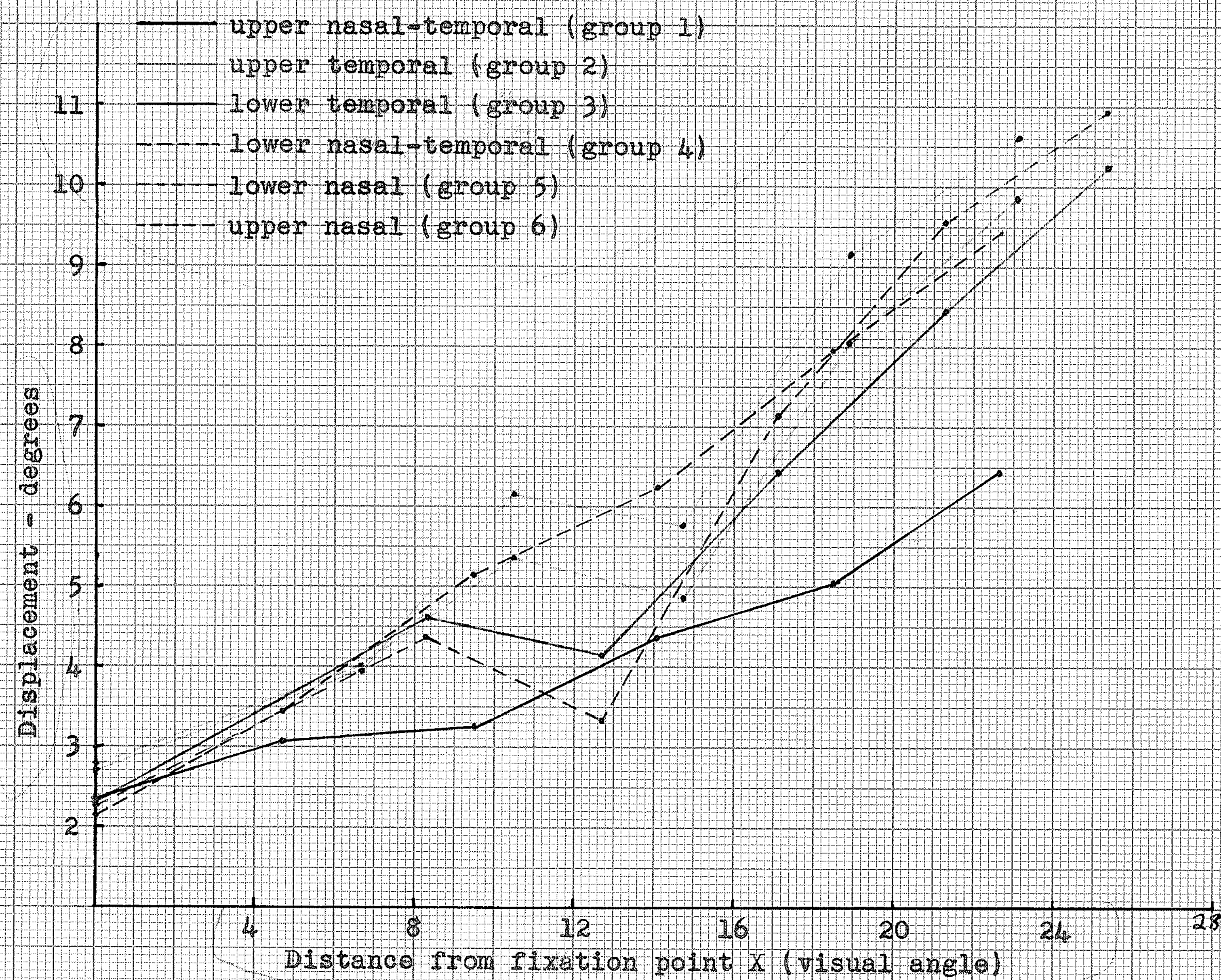

Figure 2 The magnitude of figural after-effects as a function of retinal locus

to 45 degrees and line V moved by the experimenter toward the vertical. The subject was then required to make both lines parallel while keeping his eye on the fixation point. After a 2-min. rest period another fixation point was selected and the same procedure was followed until all the fixation points in a group had been used.

Twenty-four university students served as subjects in this experiment.

Results

In all, 36 fixation points were used, six points in each of six retinal areas. Each subject made one control setting and one experimental setting at each fixation point. The difference between the appropriate control and experimental setting represents the magnitude, negative or positive, of the figural after-effect. For each fixation point these magnitudes were algebraically summed and averaged ($N = 24$).

Figure 2 displays the plots of the 6 fixation points in each of the retinal areas investigated. The increase in magnitude of the figural after-effect with increased distance from the fovea is apparent as well as the general conformity of patterns found in the different retinal areas. Table I shows the same data.

First a two way analysis of variance was carried out with the rows representing distance from fovea and the columns different retinal areas. The values of F for the rows is 55.70, for the columns 5.54. Both are significant at better than the 1% level.

TABLE I

MEAN MAGNITUDES OF DISPLACEMENT FOR SIX RETINAL AREAS (in degrees)

Points from fovea to periphery	Group of fixation points					
	1	2	3	4	5	6
I (or X)	2.37	2.70	2.33	2.14	2.77	2.27
II	3.08	3.95	4.60	3.43	4.00	4.37
III	3.22	6.14	4.16	5.14	5.39	3.33
IV	4.35	5.77	6.41	6.27	4.87	7.12
V	5.02	9.12	8.41	7.93	8.02	9.54
VI	6.41	10.60	10.33	9.43	9.85	10.95
F values	6.55	20.19	12.07	9.97	12.74	20.78
Kendall's W	.236	.454	.506	.382	.507	.556

An inspection of Table I suggests that column 1, representing the data for the upper nasal-temporal retinal area, contributes largely to the value of F for the columns. To check this column 1 was eliminated and an analysis of variance was carried out on the remaining five positions. Here the value of F for rows is 82.80, for columns .92. The increase in the value of F for rows reflects the effect of the relatively narrow range of scores within column 1, while the value of F for columns indicates that the first value of F for columns (5.54) depended on the contribution of column 1 (upper nasal-temporal retinal area).

To determine whether the significant over-all relation between distance from fovea and size of the figural after-effect held for each retinal area the value of F was calculated for each. The results are shown at the foot of each column in Table I. The relationship is reliably found in each area tested.

Apart from over-all or general pattern of results it may be asked whether each individual subject conformed to the general pattern, that is, to what extent did each subject show increasing figural after-effects as the distance from the fovea was increased? To answer this Kendall's Coefficient of Concordance (W) was calculated for each retinal area. These values are found at the foot of each column in Table I. All are significant. Even though only a single measure was taken at each fixation point for each subject, individual results produce a significantly consistent pattern.

Thus generally it may be said that the magnitude of figural after-effects is significantly related to the distance of the inspection- and test-figures from the fovea in all retinal areas tested. As between retinal areas no significant differences are found among five of these. The upper nasal-temporal area, however, stands apart from the rest in producing significantly smaller after-effects than the other areas.

It may be noted that although a gradual increase in the magnitude of the figural after-effect was obtained as the distance of the figures from the fovea was increased, there were a few exceptions. Examination of Figure 1 shows that there was a decrease in the amount of displacement between approximately 8° and 12° of visual angle from fixation point X in the upper nasal and lower temporal areas, and a decrease approximately between 11° and 15° in the lower nasal and upper temporal retinal regions.

Discussion

The nature of the inspection- and test-figures employed in this study requires some consideration. The use of the same two lines as both inspection- and test-figures was chosen on the experience of Gibson and Radner (1937) and Köhler and Wallach (1944) as the best means of reliably producing sizeable figural after-effects. The length of the lines (3") was designed to reduce the frequency of disappearance of the figures under conditions of peripheral viewing commonly reported (See Day, 1957, p. 45). Even with the 3" line all subjects complained of the fading which occurred in the outermost fixation points. However, the shift of the inspection-figures to the test positions restored the image and permitted the required judgments to be made.

It is necessary to point out that as a consequence of using these large figures the points plotted in Figure 1 represent a retinal locus lying centrally between two "satiated" areas, the centers of which are separated by approximately 4° of visual angle. The amount of displacement shown, therefore, is the sum of the displacements occurring in two areas.

Despite the fact that the fixation points do not precisely locate the locus of the effects the main results are clear in displaying an increase in the magnitude of the figural after-effect as a function of distance from the fovea. The trend, on the whole, is for a consistent rate of increase though the data suggest some deviations from this pattern. The data, as they are, discourage the attribution of any real significance to these deviations. They are discussed later, but only to suggest the possible presence of problems within the broader framework of the present findings.

One point that emerges as an apparently reliable phenomenon is the difference between the magnitudes of the figural after-effect occurring along the upper vertical median meridian (upper nasal-temporal region) of the retina and all other retinal loci tested. This result becomes the more notable because it runs counter to observations made by Köhler and Wallach (1944, pp. 281 and 304) where figural after-effects in the lower visual field are reported as stronger than those in the upper visual field, while in the present data they turn out to be significantly weaker. In the Köhler and Wallach figures it is not possible to deduce the exact retinal locus of the effects but almost certainly they occurred close to the foveal area. In the present data no appreciable differences are found in different retinal areas within four degrees of the fovea.

There remain only two rather doubtful points of the data to be considered. These were foreshadowed two paragraphs above.

In four of the six areas investigated the consistent trend of increasing figural after-effects with increasing distance from the fovea is reversed at more or less the same distance from the fovea. In the lower temporal and upper nasal areas (fixation points running diagonally) there is a reduction of figural after-effects between the points lying at approximately 8° and 12° of visual angle. A similar reversal occurs in the upper temporal and lower nasal areas (all of these points lying close to the horizontal median meridian): these occur between the fixation points lying approximately at 11° and 15°. While the decline in magnitude of figural after-effects within this area is not marked enough to produce a feeling of confidence that it reflects a real state of affairs, it is striking enough to suggest, at least, that there is a plateau within which the usual functional relationship of magnitude and distance do not hold. Methods yielding a more precise measure of the locus of effects need to be used to confirm what these data suggest. Such methods should be feasible within the areas up to 15° of visual angle without too much disturbance from the fading of the peripheral image.

There is a temptation to speculate on the reasons for the increase in magnitude of the figural after-effect toward the periphery, but the complexity of factors within the retina together with the speculative elements in both the satiation and statistical theories provide sufficient grounds for resisting the temptation.

Two aspects of retinal structure are suggestive of a possible basis. The first is the increasing ratio of receptors to inner nuclei from fovea to periphery (See Day, 1957, p. 41), the second is the ratio of cones to rods (See Geldard, 1953, p. 25); these, of course, are not unrelated. However, precise deductions are made improbable by the complicating factors of convergence and reciprocal overlap which have their effects on the final cortical representation. Day's argument as far as the retina is concerned takes account only of the ratio of receptors to inner nuclei and it seems quite clear that the density of receptor populations will play a role in determining the shape and intensity of cortical excitation.

The present results do not provide the regular constant increase of magnitude which would be implied by the receptor-inner nuclei ratios, nor do they fit the pattern of cone-rod distribution, nor the pattern of density of receptor populations. Some combination of these factors may provide a key, but until data possessing more precision than those reported here they must be left simply as empirical results.

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CHAPTER III

EXPERIMENT II: METHOD, RESULTS AND DISCUSSION

I. PART A

The Problem

It was indicated in Chapter I that both the theories proposed to explain figural after-effects predict the 'distance paradox' phenomenon. Previous investigations of this phenomenon employed outline figures such as rectangles, circles, etc. as inspection-figures. It was noted, too, that such figures produce patterns of satiation which differ from those produced by single lines. Disputes concerning the interpretation of phenomena associated with the 'distance paradox' may be related to these different pattern of satiation. But in order to support this speculation it is necessary to provide empirical data concerning the 'distance paradox' when single lines are used as experimental figures. This is the purpose of Part A of Experiment II.

Apparatus

A diagram of the inspection- and test-figures is shown in Figure 3. The fixation point (F) is ¼" to the left and mid-way between the lines V and I-T. The line marked V is ½" above line I-T, and both are 2" long and approximately .005" wide.

The apparatus consists of a metal box 8 X 8 X 8 with a 4 X 5" opening in the front. Inside this metal box and

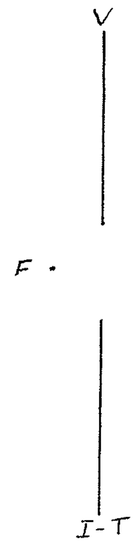

Figure 3 Diagram of Inspection- and Test-figures

covering the opening are two aluminum slides each 3 X 6½" and each with a 2 X 2" hole in the center. These two slides are fastened in rails and can be moved horizontally. A piece of 2¼ X 5" transparent plastic, which was painted black and a 2¼" long and .005" wide opening (V and I-T lines) made in the center, is attached to each slide with the V and I-T lines in the center of the 2 X 2" openings. Behind each of these lines and fastened to the slide is a 7½ watt bulb. The bulb fastened to the upper slide is connected to a separate switch and both bulbs are controlled by a master-switch. Between the aluminum slides a 8 X 8" tin plate is horizontally fastened, dividing the box into two parts.

The metal box is fixed in a wooden frame and placed on a table so that the fixation point, which consists of a small red light, is at eye-level to the subject seated at the table. The lower slide which carries the vertical inspection- and test-line can be moved horizontally by the experimenter. The upper slide holding line V is attached to a number of gears to which a rod is connected which can be turned by the subject, thus horizontally moving the variable line (V). The exact movement of each slide is read from a scale which is correct to .005". A pilot light is fastened above the scale and a cardboard shield, with an opening in front of the metal box, is used to prevent light behind the apparatus from reaching the subject. A chin-rest is situated 24" in front of the apparatus and the subject views the figures through a black cardboard 'tunnel'.

Procedure

The subject is seated and comfortably adjusted to the chin-rest and requested to focus on the red fixation point at all times. Initial practise is given in aligning the upper variable line with the lower line, coming in from both left and right. Ten second rest periods are given between trials. This is continued until the subject can make relatively consistent adjustments within a period of 6 to 8 seconds.

At this point the subject is given a two minute rest period and then required to make four alignments as before, two from the left and two from the right. These four measures, averaged, define his point of subjective equality which serves as a reference point for measuring the figural after-effect (if any) that occur in the immediately following experimental period.

At least two minutes visual rest is given after securing the control measures. Sufficient time is taken to ensure that the subject fully understands what he is to do, that is, to focus on the fixation point for 60 seconds while only the lower line is illuminated. At the end of this time the upper line will also be illuminated and he is to align the top and bottom lines as in the control period.

During the inspection period the lower line (I-figure) is positioned at the appropriate distance from true zero (test-position) for that experimental condition. At the end of the inspection period it is returned to the test-position at which time the upper variable line is illuminated and the subject then makes the necessary adjustment. This procedure is carried out eight times allowing a two minute rest interval between trials. As in the control session the variable line is placed alternately to the left and right of the T-figure.

Each subject appeared for six experimental sessions usually one day apart. In each session one position of the I-line was used. The various distances of the I-line from the test-position were as follows (in inches): coincidence, .062, .125, .250, .375, .750.

Eleven university students were used as subjects.

Results

At the beginning of each experimental session each subject made four control settings of the variable line, two from the left and two from the right. This was followed by eight experimental settings, four from the left and four from the right, each made after a 60 second inspection period. The four control settings are averaged as are the eight experimental settings. The difference between these averages represents the magnitude of the figural after-effect.

Each entry in Table II represents such a result for a given subject in a given experimental condition. The mean value of the eleven subjects for each condition is shown at the foot of each column. These mean values are plotted in Figure 4.

There is no displacement of the T-line at coincidence and a rapid increase in the magnitude of displacement occurs reaching a maximum for the condition in which the inspection-line was placed .125 inches from the test-position. There follows a decline more gradual than the initial ascent and with evidence of figural after-effects still present at the limits tested (.750 inches).

In view of the regular upward and downward trend only three statistical checks appear necessary; t tests were made for the following comparisons. 1. Between control settings and the settings at coincidence $t = .27$, $p > .70 < .80$, that is, there is no evidence of displacement at coincidence. 2. Between the magnitude of the after-effect at

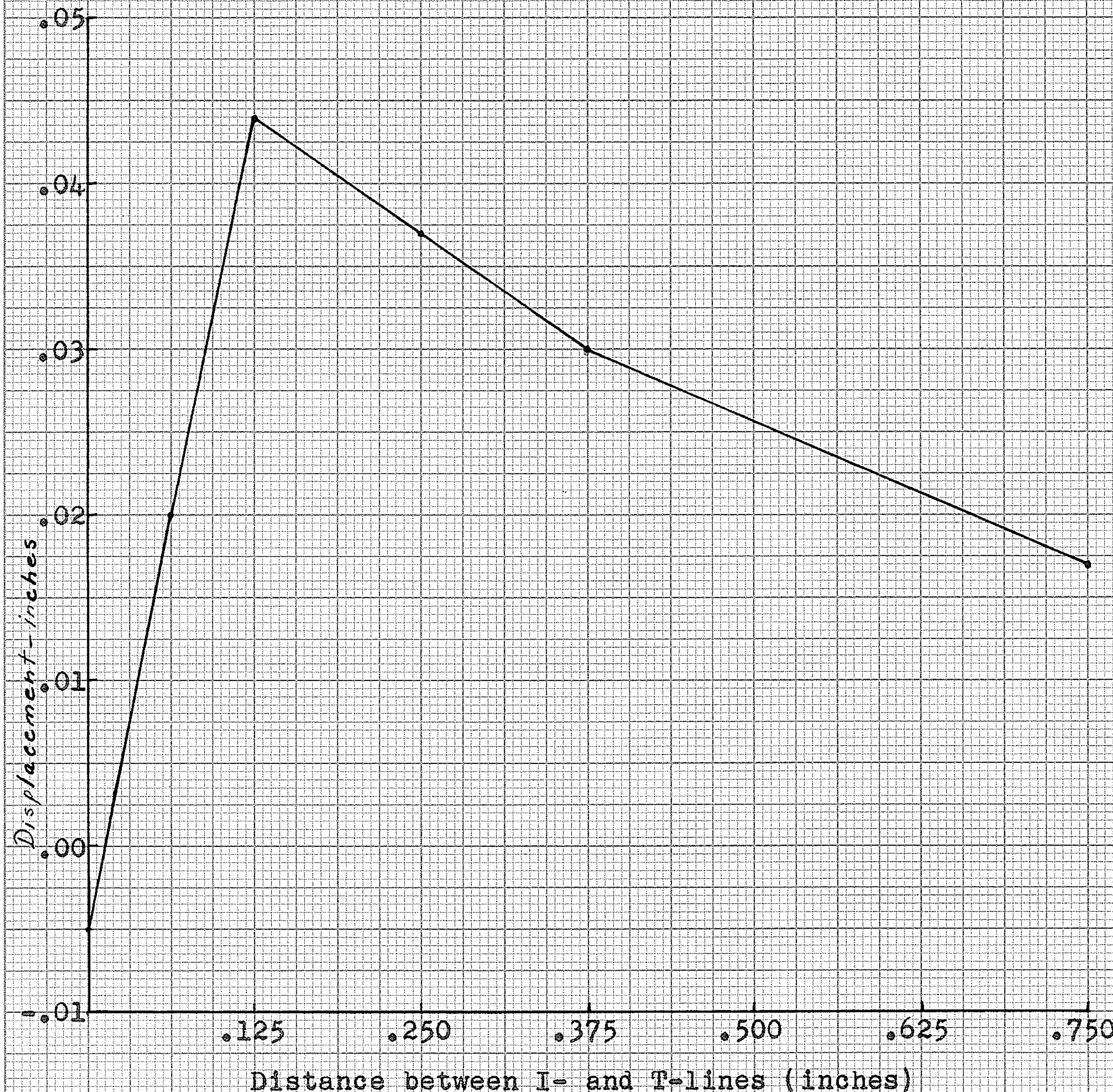

Figure 4 Displacement of a test-line as a function of the distance from an inspection-line.

TABLE II

INDIVIDUAL AND MEAN DISPLACEMENTS AS A FUNCTION OF THE DISTANCE BETWEEN INSPECTION- AND TEST-FIGURES (in inches)

Subj.	Coin.	.062"	.125"	.250"	.375"	.750"
1	+.029	+.033	+.074	+.079	+.093	+.074
2	-.001	+.051	+.045	+.031	+.039	-.004
3	+.043	+.013	+.047	+.002	+.049	-.009
4	-.018	-.023	+.040	+.035	+.008	+.008
5	-.022	-.005	+.055	+.093	+.025	+.033
6	-.023	+.084	+.008	-.003	+.029	+.022
7	-.037	+.010	+.049	+.020	+.005	-.009
8	-.030	+.027	+.054	+.053	+.016	+.024
9	+.003	+.019	+.051	+.053	+.020	.000
10	+.016	+.025	+.028	.000	+.013	+.037
11	-.013	-.009	+.032	+.049	+.032	+.011
Mean	-.005	+.020	+.044	+.037	+.030	+.017

coincidence and at the point of maximum displacement (.125 inches) there is a significant increase ($t = 5.326$, $p < .01$).
3. Between the point of maximum displacement and the extreme tested (.750 inches) $t = 2.967$, $p < .01$, that is, there is a significant decline from the maximum point.

II. PART B

The Problem

In dealing with the 'distance paradox' phenomenon both the satiation and statistical theories clearly predict no displacement at coincidence when a single straight line is used as inspection- and test-figures. Part A produced data supporting this prediction as well as displaying the 'typical' distance paradox curve.

The situation is not so clear in the case of outline figures such as rectangles, circles, etc. As mentioned in Chapter I Köhler et al. (1944, p. 351; 1950a, p. 269) claim that with such figures asymmetrical patterns of satiation are produced which will result in the displacement of a T-contour coincident with such an I-figure. Osgood and Heyer (1952, p. 106) and Osgood (1953a, p. 212), assuming that reported displacements at coincidence with outline figures can be explained by paleness cues, predict that no 'real' displacement occurs at coincidence.

What seems to be desirable is a comparison between coincidence using a single straight line (Part A) and coincidence, using the same method of measurement, under conditions of so-called asymmetrical satiation, as well as a technique in which possible paleness cues will not affect the results. This is the purpose of Part B of Experiment II in which the same apparatus and conditions as in Part A are used, with one exception. In the place of the single vertical line used as the I-figure in Part A, two vertically parallel lines are used. This figure presumably produces asymmetrical satiation and the results obtained may not be interpreted on the basis of paling of contours.

Procedure

Figure 5 shows what was displayed in the apparatus described in Part A. The display differs from that in Part A (Figure 3) in that the lower slide now has an

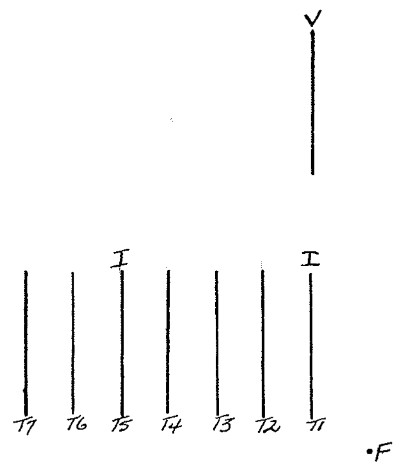

Figure 5 Diagram of Inspection- and Test-figures

inspection-figure of two vertical lines ¾" long and separated by 1". Successive test-positions are separated by 0.25" and the fixation point (F) is to the right and below the lower right hand line.

Figure 5 shows the relative positions of inspection- and test-figures though the operational procedure was always to have the test-line in the position labelled T1, that is, the distance from the fixation point was held constant for each test condition. The relative positions of inspection- and test-figures was secured by moving the inspection-lines to the right. At the end of the inspection period a single line was placed in the position T1 and, as in the experiment in Part A, the subject adjusted the variable line. The control measures were secured in the same fashion as in Part A.

In each experimental session, using a 60 sec.

inspection period and a two minute rest period between trials, one measure on each test position was obtained. Each subject served in four sessions which were separated by approximately a day. In each session a different order of experimental conditions was used so that over the whole series a counter-balanced order was achieved.

Seven university students who participated in Part A served as subjects.

Results

As in the previous experiment the magnitude of the figural after-effect is the difference between the average of the control and experimental settings. The results are shown in Table III. Figure 6 shows the mean value and direction of the figural after-effect at each test position: negative values indicate displacement to the left, positive values to the right.

The points of particular interest are positions T1 and T5 where inspection- and test-lines are coincident. It will be noted that there are displacements at both points and that the displacements are in opposite directions, so that both are displaced inward corresponding to the shrinkage effect reported for outline figures.

At the foot of each column in Table III are the values of t when the control and the experimental readings are compared for each of the test positions. It will be observed that the displacement at T5 is significant while

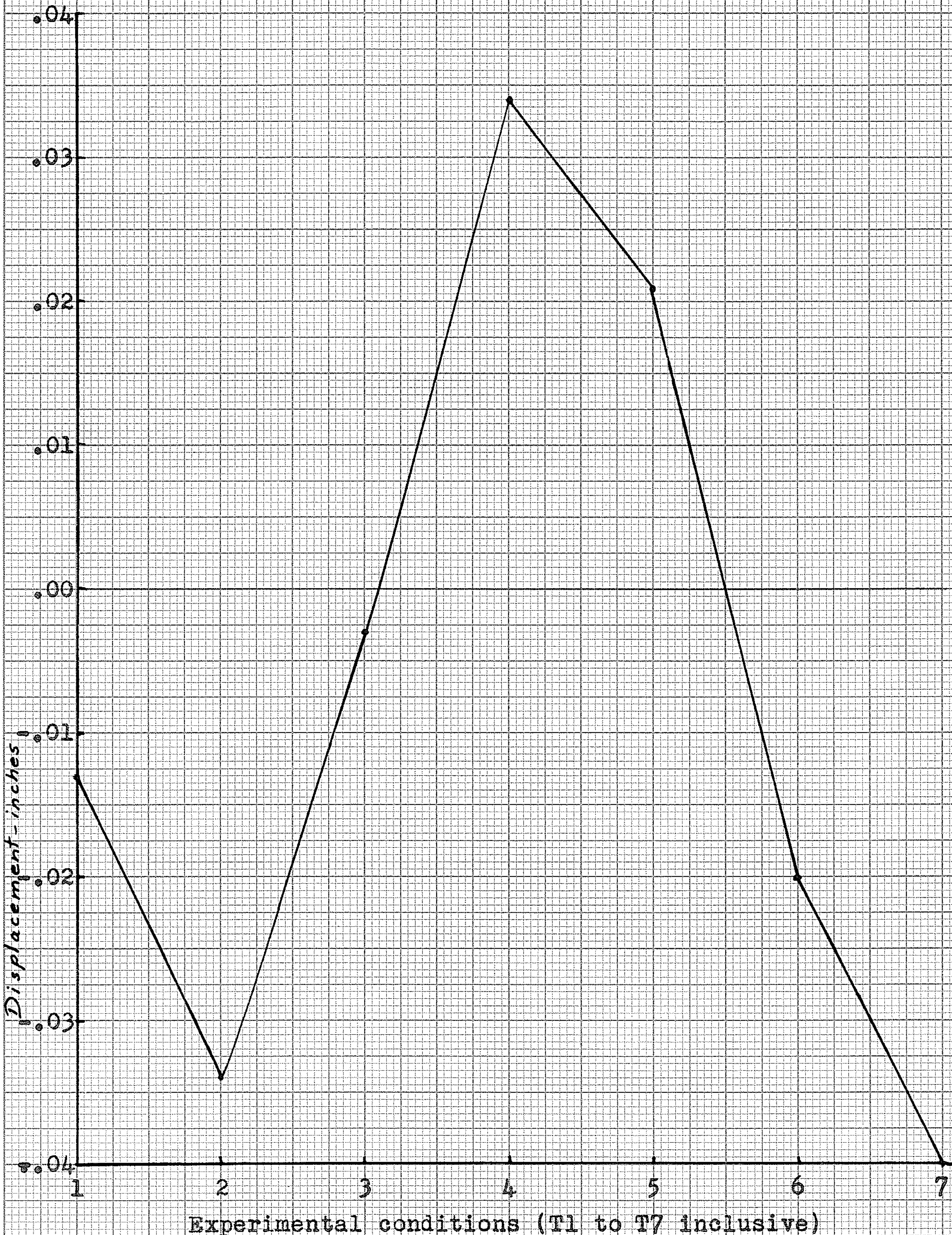

Figure 6 Displacement of a test-line under various experimental conditions.

TABLE III

INDIVIDUAL AND MEAN DISPLACEMENTS UNDER SEVEN EXPERIMENTAL CONDITIONS (in inches)

Subj.	Experimental Condition						
	T1	T2	T3	T4	T5	T6	T7
1	-.010	-.007	-.007	+.040	+.035	-.007	-.002
2	-.006	-.036	+.012	+.044	+.012	-.003	-.026
3	+.003	-.027	+.006	+.033	+.028	-.012	-.032
4	-.007	-.034	-.017	+.011	-.002	-.042	-.039
5	-.022	-.049	-.024	+.016	+.001	-.047	-.072
6	-.020	-.055	-.007	+.028	+.028	-.025	-.057
7	-.031	-.031	+.019	+.066	+.044	-.004	-.051
Mean	-.013	-.034	-.003	+.034	+.021	-.020	-.040
T score	1.845 x	4.333	.342 x	3.886	2.255	2.302	5.307

x Not Significant

that at T1 falls short.

All other test positions show significant differences from the control except T3. T3 falls in the center of the inspection-lines and shows no evidence of displacement.

One other set of comparisons is of interest, that is, corresponding positions inside and outside the inspection-figure. In each case T2 vs. T6 and T3 vs. T7 the magnitudes of displacement are different. The value of t for the first pair is 1.907 and falls just short of being statistically significant; the second pair, T3 and T7, yields a t value of 5.027, significant beyond the 1% level.

III. DISCUSSION

The primary outcome of Experiment II is basically two-fold. Part A demonstrates the 'distance paradox' phenomenon and shows that no displacement of a test-contour takes place when coincident with a single straight line used as an inspection-figure. Part B shows that test-contours coincident with two vertically parallel lines are displaced inward or toward each other. Both parts of Experiment II will now be discussed.

When a single line is used as an inspection-figure both the satiation and statistical theories predict the 'distance paradox' phenomenon. That is, when a single I- and T-line coincides there is no displacement of the latter, but as the contours are gradually separated displacement of the T-line increases, reaches a point of maximum displacement and then decreases. Other investigators (Fox, 1951; Ikeda, 1951; Ikeda and Obonai, 1955; Kogiso, unpubl.; Köhler and Wallach, 1944; Oyama, 1954) have also demonstrated this phenomenon except that displacement was reported at coincidence. These investigators, however, used outline figures such as rectangles and circles which, according to the satiation theory, produce a different pattern of satiation than a single line. This leads to Part B of Experiment II.

In Chapter I it was stated that according to Köhler and Wallach's satiation theory when I- and T-lines are used the pattern of satiation is the <u>same or symmetrical</u> on both sides of the lines and, therefore, the T-line cannot be displaced when it coincides with the I-figure (1944, p. 351). With outline figures, or those having curves or angles, however, satiation will <u>not</u> be the same on both sides (inside and outside) of these figures (1944, p. 351; 1950a, p. 269). In other words, with such figures so-called asymmetrical patterns of satiation are produced which result in the displacement of the coincident figure (1950a, p. 268). Both parts of Experiment II confirm these predictions.

Osgood and Heyer, authors of the statistical theory, assume that reported displacements at coincidence may be explained by paleness cues and predict that no displacement occurs at coincidence with outline figures (Osgood and Heyer, 1952, p. 106; Osgood, 1953a, p. 212). Part B has demonstrated that displacement at coincidence does occur which cannot be explained on the basis of paling of contours. Earlier investigators mentioned above who studied the same problem have reported results in agreement with those obtained in the second part of Experiment II.

Returning to the satiation theory it seems that the factor which determines whether displacement will or will not take place when I- and T-figures coincide is the nature of the <u>pattern</u> or distribution of satiation on both sides of a given point. In the case of a single inspection- and test-line the pattern of satiation, according to Köhler and

Wallach (1944, p. 351), is the same or symmetrical on both sides of these figures and, therefore, no displacement can occur at coincidence. Such a situation presumably existed in Part A since no displacement was recorded at coincidence. According to Köhler (personal communication) satiation was also symmetrical with respect to position T3 in Part B where no displacement occurred (T3 is not coincident with the I-figure as in Part A, but lies at the 'balance' between the I-lines).

It seems that if satiation is symmetrically distributed on both sides of a point or line, according to the satiation theory similar magnitudes of displacement should take place at comparable locations on either side of such a point. This is confirmed with respect to line T3. There is no significant difference in the magnitude of displacement at points T2 and T4 (each 0.25" from T3), and no significant difference between T1 and T5 (each 0.5" from T3).

As mentioned earlier, according to the satiation theory, outline figures produce so-called patterns of asymmetrical satiation. When asymmetrical satiation is established with respect to the contours of a figure, it seems that two 'displacement phenomena' should be observed: (1) a T-object should be displaced when coincident with the I-figure and, (2) different magnitudes of displacement should be observed at corresponding points inside and outside such a figure. Both phenomena are verified by the results obtained in Part B. As well as obtaining displacement at coincidence, it was also found that T2 and T6 which are at comparable points (each 0.25" from an I-line) inside and outside the I-figure were displaced by almost significantly different magnitudes. At another pair of comparable points, T3 and T7 (each 0.5" from an I-line), there was a significant difference in the magnitude of the figural after-effect. It seems reasonable, therefore, to conclude that there existed an asymmetrical pattern of satiation inside as compared to outside the figure used in Part B which produced displacement at coincidence and the different magnitudes of displacement at corresponding points in the interior and exterior of the I-figure.

From the results of Experiment II it seems that the investigations of Fox (1951), Ikeda (1951), Ikeda and Obonai (1955), Kogiso (unpubl.) and Oyama (1954) are cast into a different 'light' from the original interpretations given by Fox (1951) and Oyama (1956b).

It was mentioned in Chapter I that Fox (1951) carried out two experiments investigating the 'distance paradox' phenomenon and reported displacement of the test-object when coincident with an inspection-rectangle in his first experiment, and no 'significant' displacement in his second. Although no significant displacement was observed in his second experiment, displacement was recorded and was in the same direction as reported in other investigations and in the present study. That is, the T-object was displaced toward the interior of the I-figure. Since Fox used rectangles as inspection-figures, which according to Köhler and Wallach and on the basis of the present study produce patterns of asymmetrical satiation, it appears that he is incorrect in assuming that no displacement should occur at coincidence (1951, p. 322, 324). From the results of the present investigation it appears that Fox's results confirm the predictions of the satiation theory, while his interpretation of that theory and of his own experimental results is misleading.

Oyama (1956b), who discussed the results of a number of investigations (Ikeda, 1951; Ikeda and Obonai, 1955; Kogiso, unpubl.; Oyama, 1954) in which a T-circle coincident with an I-circle was displaced, stated that this was evidence against the satiation theory. According to Oyama's interpretation of Köhler and Wallach's theory, no displacement should have occurred in such a situation. As in Fox's case, this interpretation of the satiation theory seems to be incorrect as the references to this theory, as well as the results of Experiment II would indicate.

Although the satiation theory predicts displacement of a test-contour coincident with an outline or curved or angular inspection-figure, the <u>direction</u> of this displacement is an important question. As was mentioned in Chapter I, Hebb (1949, pp. 54-58) claims that according to the satiation theory a test-figure coincident with an inspection-figure, such as a square or circle, should increase in size, or be displaced toward the exterior of the inspection-figure.

Köhler and Wallach (1944), as well as more recent investigators (Fox, 1951; Ikeda, 1951; Ikeda and Obonai, 1955; Kogiso, unpubl.; Oyama, 1954, 1956b), however, have reported the opposite. That is, the test-object shrinks or is displaced toward the interior of the inspection-pattern. The same results were also obtained in the present study (Part B).

According to Köhler and Wallach "The distance between visual objects varies with the degree to which corresponding cortical objects are interrelated by their figure currents" (1944, p. 334). They further state that when the functional interrelation between objects is weakened (i.e., when there is a decrease in the flow of current between objects) the distance between them grows; when the interrelation is strengthened, the distance decreases (pp. 336-337). Hebb argues that since a T-figure coincident with a previously inspected I-figure lies within a satiated region, the functional interrelation between the opposite sides of this figure will be weakened and, therefore, according to the Köhler-Wallach theory, the figure should be increased in size, or be displaced toward the outside of the inspection-figure.

It was also mentioned earlier that Köhler and Wallach claim that with outline figures an asymmetrical pattern of satiation is produced, with the level of satiation being greater inside than outside the figure (1944, p. 351; 1950a, p. 269; 1950b, p. 402). They also state that displacement of a contour occurs from an area of greater satiation to a region of less satiation (1944, pp. 335, 349; 1950a, p. 268).

According to these references it would seem that a T-figure coincident with an outline I-figure should increase in size, or be displaced toward the exterior of the inspection-pattern.

On the basis of Hebb's interpretation and the above references it would seem that although Köhler and Wallach's satiation theory predicts displacement at coincidence with outline inspection-figures, the direction of that displacement is not clearly explained, or, in fact, appears to be contrary to the reported results. If the above interpretations of the satiation theory are correct, it does not necessarily mean that this theory has been contradicted by experimental evidence. Rather it seems that further investigation is required in order to work out the theory in greater detail as Köhler and Wallach themselves have indicated (1944, p. 357).

CHAPTER IV

SUMMARY AND CONCLUSIONS

Two aspects of figural after-effect phenomena were investigated: (1) the magnitude of the figural after-effect as a function of retinal locus, and (2) the 'distance paradox' with particular attention upon the situation in which the experimental figures coincide under conditions of so-called symmetrical and asymmetrical satiation.

A consistent relationship between retinal locus and the magnitude of the figural after-effect was demonstrated in the first experiment. The second experiment displayed the 'typical' distance paradox curve and showed that no displacement occurred at coincidence with symmetrical satiation, but under asymmetrical satiation the 'displacement' phenomenon was observed.

The results concerning the distance paradox are compared with those of earlier investigations and discussed in relation to Köhler and Wallach's satiation theory and Osgood and Heyer's statistical theory.

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