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KOEHLER'S SATIATION THEORY AND DEUTSCH'S  
NEUROPHYSIOLOGICAL MODEL OF FIGURAL AFTER-EFFECTS

A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfilment of the Requirements

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by

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CHAPTER I

INTRODUCTION

A lifetime of work by Gestalt psychologists has culminated in an electrical field theory of cerebral integration which represents an attempt to explain a number of visual phenomena and even provide a bridge between the general areas of perception and learning (Koehler, 1958, 1965; Koehler & Fishback, 1950a, 1950b; Koehler & Wallach, 1944). One of the main objections to this theory is that it is not based upon orthodox physiological principles. According to Prentice, for example, Koehler's theory is regarded as a radical departure from current physiological knowledge of the nervous system because it suggests "...the importance of physical phenomena other than those that follow anatomical pathways" (1962, p. 46).

In 1952 Osgood and Heyer presented a theory which they claimed could explain most of the visual phenomena of Koehler's theory, and which was based on known physiological principles. The logical consistency and neurophysiological assumptions of this theory have since been questioned (Deutsch, 1956), and these assumptions have never been subjected to experimental examination as has been the case with Koehler's theory (Day, Pollack & Seagram, 1959).

Using some of the most recent neurophysiological findings, Deutsch (1964) presented a model which was designed to account for the phenomena covered by the two earlier theories. At present, however, no experimental data are available either to evaluate this theory or to compare it with

Koehler's or Osgood's models. Therefore the purpose of the present investigation is to test some of the predictions of this latest theoretical attempt and compare it with the earlier positions.

Because most of the predictions of Koehler's satiation theory, Osgood's statistical theory and Deutsch's neurophysiological theory are made in terms of figural after-effects, the present investigations will be largely restricted to these phenomena. In the following sections these phenomena will be described and the three theories broadly outlined. Some of the predictions of these models and relevant experimental evidence will be discussed, and the results of experiments designed to test these predictions will be described. In the final section of this study these theories will be evaluated in the light of the present and earlier experimental results.

### 1.1. Discovery and Description of Figural After-Effects

In 1925 Verhoeff reported that if a line, bent at an obtuse angle about its middle, is fixated for a period of time, a subsequently exposed straight line will appear bent in the opposite direction. This is the first report of a figural after-effect (FAE), although credit for the discovery, according to McEwen (1958) is given to Gibson (1933). Gibson reported that subjects wearing prisms that made straight objects appear curved resulted in decreasing curvature as the subjects continued to wear them.

When the prisms were removed, objectively straight objects appeared curved in the opposite direction to that produced by the spectacles.

Gibson also showed that if a curved line is viewed for a period of time and then replaced by a straight line, the latter will appear curved in a direction opposite to that of the former.

While Gibson (1933, 1937a, 1937b) was studying the above after-effects, Koehler was concerned with the fundamental problem of how visual patterns become organized into the objects people see, and was using the reversible or ambiguous figure as his experimental tool (Prentice, 1962). When Gibson's findings came to Koehler's attention, he realized the similarity between figural after-effects and reversible figures and began to study the former in a variety of situations.

In 1944 Koehler and Wallach gave a detailed report of figural after-effects and presented a theoretical account of these phenomena. The following example will illustrate the nature of these visual phenomena. A subject is seated with his head in a headrest to minimize head movements. He is then shown a large cardboard screen bearing two circles of equal size with a fixation point between them. This is called the test (T-) figure. He is instructed to look at the fixation mark, compare the two figures, and report any differences between them. Since these two figures are objectively the same, no differences are expected. The card

is then removed and replaced by another card called the inspection (I-) figure. This card also has a fixation mark but only one circle to the left of the mark. This circle is concentric with the left circle of the test figure and is somewhat larger in size. The subject is asked to look at the fixation mark on the inspection card for one or more minutes. The card is removed and replaced by the test card. While looking at the fixation mark, the subject again reports any differences between the two test circles. Most subjects report that the left circle appears paler, smaller, further back or displaced in space as compared with the one on the right.

The most striking of these phenomena is the apparent displacement of a contour. Consequently, most investigations of figural after-effects have been concerned only with this displacement effect. Therefore the experimental findings referred to in this study as well as the experiments that will be carried out will deal mainly with the phenomenal displacement of contours.

In 1944 Koehler and Wallach formulated a theory, called the satiation theory, to account for these figural after-effects. A broad outline of this theory and some tests of its basic physiological assumption will now be reviewed.

## 1.2. The Satiation Theory

Koehler claims that his theory contains only one assumption, namely, that, "...when we see an object, an electric current flows through and around the corresponding part of the visual cortex" (1965, p. 66). As this current flows through the cortical tissue it establishes resistance in the tissue to continued flow with the result that the current will be deflected into less affected regions. Koehler called this resistance to current flow, satiation.

What will happen when an inspection figure is exposed in the visual field for a period of time? According to the satiation theory, figure currents will flow in the corresponding area of the visual cortex leaving a pattern of obstruction to further currents. When the test figure is shown the test currents will not have the same distribution as they had before the inspection figure was shown, but will be deflected into tissue having less resistance to the flow of these currents. It is this deflection of the test figure currents that results in the phenomenal displacement of the test contour.

One of the major objections to Koehler's theory is that it represents a radical departure from orthodox physiological principles. Koehler (1958) has pointed out that the cortical currents or fields postulated in his theory differ from the conventional nerve impulses in three respects. In the first

place these currents are graded processes and do not follow the all-or-none law of impulses. Secondly, these currents have not the form of short-lived waves which characterize the nerve impulses and electrical rhythms of cortical cells, but rather are "...quasi-steady states"

(p. 152). Thirdly, the currents of Koehler's theory spread freely in the tissue while the nerve impulses follow the nerve fibers.

Koehler and his collaborators (1949, 1951, 1952, 1955a, 1955b, 1957) have reported numerous records of figure currents in the visual and auditory cortices taken from humans and from the exposed projection areas of cats, which they claim strongly support their theory of figural after-effects. Lashley, Chow and Semmes (1951), Sperry and Miner (1955) and Sperry, Miner and Myers (1955), however, have provided evidence which questions the existence or importance of Koehler's hypothesized figure currents.

Lashley, Chow and Semmes (1951), attempting to examine the basic assumption of the satiation theory, laid strips of gold foil on the visual cortex of a monkey, and pushed pieces of this material into the cortex of another animal. They assumed that since the gold foil was a better conductor than the cortical tissue, the flow of current would be deflected from its normal course and thus disturb pattern vision. When postoperative tests showed no disturbance, they concluded that perceptual organization cannot

be related to such currents. Sperry and Miner (1955) and Sperry, Miner and Myers (1955) performed similar tests on cats and found that the animals' ability to discriminate between various visual patterns was not affected. Although Koehler (1958, 1965) has challenged the interpretation and reliability of these findings, he nevertheless admits that his theory is not based on well-known physiological principles.

### 1.3. Osgood and Heyer's Statistical Theory

In 1952 Osgood and Heyer presented a theory of figural after-effect phenomena which they claimed was based upon "...accepted neurophysiological principles concerning a nervous system composed of single neurones with precise connections" (p. 117). Although this model initially stimulated considerable investigation, no attempt has been made to subject its physiological assumptions to experimental examination as has been done with Koehler's satiation theory. Since the statistical model can only be usefully tested against the satiation theory in terms of physiological evidence (Day, Pollack & Seagram, 1959), no attempt will be made in the present investigation to compare the two positions. The experiments in this study, therefore, will be concerned only with the predictions of Koehler's theory and the theoretical position (Deutsch, 1964) which will now be outlined.

#### 1.4. Deutsch's Neurophysiological Theory

In 1964 Deutsch presented a theory of figural after-effects based upon some of the most recent neurophysiological principles available. The findings he used were those reported by Ratliff (1961) on the eye of *Limulus* (horseshoe crab). Ratliff has shown that when a visual receptor (ommatidium) is excited with a beam of light, it will inhibit other less excited units; the degree of such inhibition decreasing with increasing distance between the units. When the light to the highly excited unit is suddenly reduced to the level of the lower unit, the former unit undergoes a transient decrease in excitability (decrease in impulses per second), while the latter unit displays an increase in excitability (increase in impulses per second).

In order to relate these transient changes in excitability to phenomenal changes in visual distance (displacement of a test contour of the figural after-effect), Deutsch assumes that "...distances between points are measured in the nervous system by taking some kind of index of excitability of the points lying between them" (1964, p. 20). If the level of excitability between two points is decreased, phenomenal distance between them will be increased; if the level of excitability is increased, phenomenal distance will be decreased.

What will happen when a vertical line (inspection figure) is fixated for

a period of time and is then replaced by two vertical and parallel lines (test figure) placed at various locations on one side of the I-line? According to Deutsch the area at and immediately around the region previously occupied by the I-line will be in a state of decreased excitability, since it was highly excited during the inspection period. Therefore, when the test figure is placed in this area immediately after the inspection figure is removed, the apparent distance between the two lines of this figure will increase. A region further from the I-line, however, will be in a state of increased excitability since it was inhibited during the inspection period. Therefore, when the test lines are placed in this region the apparent distance between them will decrease.

### 1.5. Theoretical Issues

The present investigation will be basically concerned with two problem areas in which Koehler's satiation theory and Deutsch's neurophysiological theory make different predictions. The first concerns the magnitude and direction of displacement of two test points located at various distances from an inspection figure. The second involves Koehler's hypothesis of immediate self-satiation in unsatiated and homogeneously satiated areas. These issues will now be discussed.

Figure 1, which is a variation of Deutsch's Figure 2 (1964, p. 21), shows the change from normal excitability (A) to decreased excitability near

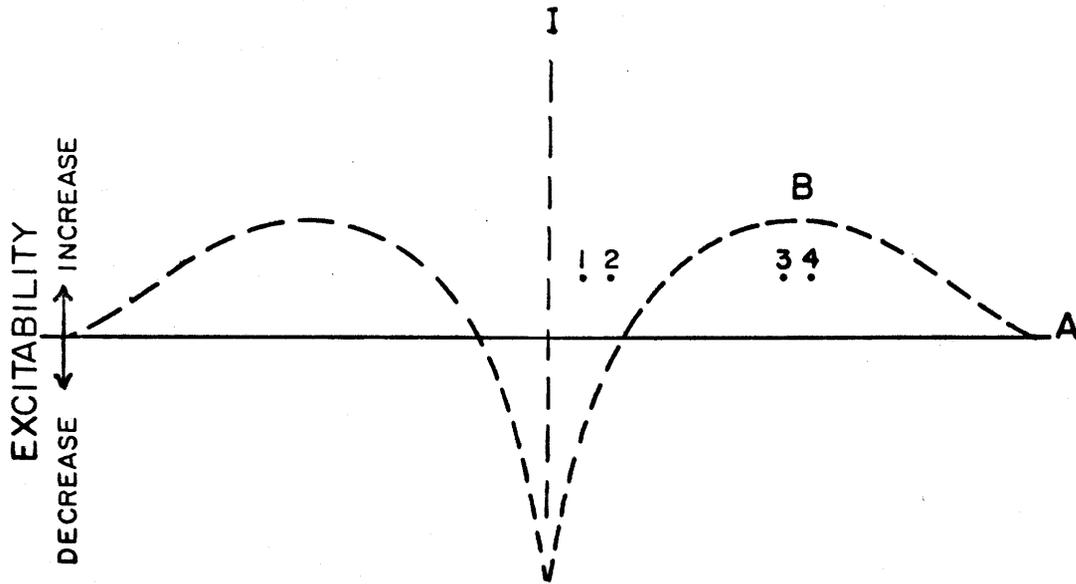


Figure 1. Changes in excitability due to the previous inspection of a contour at I. A represents normal level of excitability before inspection; B the deviation from it following inspection. Points 1 and 2 are in a region of decreased excitability; 3 and 4 in increased excitability.

the line marked I, and increased excitability at some distance from the I-line (B), following inspection of a line (I). According to Deutsch's theory the apparent distance between the test points 1 and 2 will be greater than the distance between similar points in an area of normal excitation (control condition), since the former are located in a region of decreased excitability. As these test points are moved further from the I-line into higher levels of excitability the phenomenal distance between them must decrease, until they are located in an area of increased excitability (T-points 3 and 4) where the apparent distance between them must be less than in the control condition. Regarding the apparent direction in which each test point is displaced, Deutsch's model suggests that points 2 and 3 must move away from the I-line, while points 1 and 4 will be displaced toward it (1964, p. 21).

According to Koehler's theory all four test points in Figure 1 must be displaced away from the inspection figure. When a line is exposed in the visual field for a period of time, satiation will develop in the corresponding area of the visual cortex with satiation being greatest at or along the inspection line and decreasing with increasing distance from the I-contour. When two test points are located anywhere on one side of the previous inspection contour, providing they lie in an area satiated by the I-line, the test currents "...which would normally flow in the direction of the affected area will now turn away from this area..." (Koehler & Wallach, 1944, p. 337). "Hence,

the current as a whole will recede from the affected region just as, in a figural after-effect, a test object recedes from the area previously occupied by an inspection object" (Koehler, 1958, p. 151).

There is considerable experimental evidence indicating that a test contour can be displaced toward an inspection figure (Kelm, 1962; Kelm, Jensen & Ramsay, 1963; Nozawa, 1953; Prysiazniuk & Kelm, 1963, 1965; Smith, 1954). Gardner (1960), however, maintains that such reports are not contrary to the satiation theory, but were in fact anticipated by Koehler and Wallach. The satiation theorists admit that a test figure may be displaced toward an I-contour provided the former is "...just adjacent..." to the latter, and "...provided that the inspection period has been sufficiently long" (Koehler & Wallach, 1944, p. 297). Despite this admission, however, they do not explain how this can happen in terms of the test figure currents which must always be deflected from areas of greater to areas of lesser satiation. Most of the above investigators regard their data as evidence against the satiation theory.

In order to test the two theoretical positions in this situation, the phenomenal displacement of two test points positioned at various distances on one side of an inspection figure must be measured. Since none of the above studies reporting displacement of a test figure toward an inspection figure has made such investigations, the purpose of the first two experiments

in the present report will be to provide such data.

Another situation that has created difficulties for the satiation theory occurs when two test lines, parallel to each other and at right angles to a previously inspected line, appear closer together than two similar test lines further from the I-line. Hebb (1949) has stated that according to the satiation theory the two test lines nearest the I-line should appear further apart than the more distant test lines. Koehler and Wallach (1944) realized the difficulty of this inspection and test figure arrangement and introduced the hypothesis of immediate self-satiation which Hebb (1949) regarded as ad hoc. Koehler has recently maintained that it is not an ad hoc hypothesis but is "...a simple consequence of our theory" (1965, p. 70).

According to the satiation theorists "...most figures should be enlarged by immediate satiation, for it is always the interior of circumscribed figures in which self-satiation is most strongly and most rapidly established" (Koehler & Wallach, 1944, pp. 355-356). Koehler claims that it is immediate satiation which causes visual objects to expand rapidly (gamma movements, for example) when they appear suddenly in the visual field (personal communication, 1960; Koehler, 1965).

Regarding the above two test lines nearest the I-line, Koehler maintains that the phenomenal distance between them will not be changed by immediate self-satiation. This is because they lie in a highly homogeneously

satiated region (homogeneous because satiation is the same between and beyond the two T-lines) where little or no additional satiation can take place. The phenomenal distance between the other test lines located further from the I-line, however, will be increased due to self-satiation since they are located in a relatively unsatiated area. "In a homogeneously and strongly satiated area not much further satiation can occur; but the distance between two comparison objects in a neutral area would be increased by that factor, inasmuch as immediate satiation of the area between these objects would be greater than satiation beyond the objects" (Koehler & Wallach, 1944, p. 356). Koehler and Wallach caution, however, that such an explanation must first be subjected to experimental examination (pp. 356-357).

Deutsch (1964) claims that this situation offers no difficulty for his theory. The test lines nearest the I-figure lie in an area of increased excitability such as points 3 and 4 in Figure 1, and must therefore appear closer together than the two lines further from the I-figure, which are located in a lower level of excitability (Deutsch, 1964, p. 22).

In order to explain displacement phenomena such as those mentioned above, Koehler seemed compelled to introduce the concepts of self-satiation and homogeneous satiation. Since Deutsch has not postulated parallel concepts, these two theoretical positions may be examined in

terms of the displacement phenomenon due to self-satiation in homogeneously satiated situations.

Self-satiation effects have been investigated by Duncan (1960), Ikeda and Obonai (1953) and Winters (1964). They report that a circle appears largest when it is first exposed in the visual field and then tends to decrease in apparent size as exposure time, or inspection time, is increased. Although these studies confirm Koehler's predicted self-satiation effects in a relatively unsatiated area, no investigations appear to have examined the predicted effects of self-satiation in a homogeneously satiated region. Therefore several experiments in the present study will attempt to measure these self-satiation effects under homogeneously satiated conditions. The various experimental conditions and theoretical predictions will be described before each experiment.

CHAPTER II

METHOD

## 2.1. Apparatus

The method of measuring the figural after-effect in this study was similar to that first employed by Hammer (1949) and more recently by Kelm (1962) and Prysiazniuk and Kelm (1963, 1965).

The apparatus consisted of two pieces of dull finished white vinylite: one 3 1/2 X 7 and the other 3 1/2 X 8 inches. They were .030 inches thick and each was fastened to a .125 inch thick steel plate of the same size. The 3 1/2 X 8 piece was placed above the 3 1/2 X 7 inch section, and both were mounted on the side of a 7 inch wide by 6 1/2 inch high by 6 inch deep metal box. The lower section was secured tightly to the metal box while the upper slide was fastened to a threaded brass block and steel rod. The rod, containing 20 threads per inch, was secured at each end by a precision-type bearing mounted inside the metal box. A one-inch diameter knob was fastened on the end of the rod which protruded from the right hand side of the apparatus. Turning of this knob permitted horizontal movement of the upper slide to the subject's left and right. The amount of movement was read from a scale which indicated the number of complete revolutions and a compass which showed the degrees of a revolution. Movement was recorded accurately to within approximately .0001 inches. The magnitudes of the figural after-effect in the following experiments (Chapter III) will all be expressed in degrees, with 7.2 degrees equal to .001 inches.

The apparatus was mounted on top of a 9 inch high white wooden box and placed on a table. A headrest, fastened to the table, was located in front of the apparatus.

The test figures were drawn on the two pieces of vinylite with black India ink. They consisted of a number of .030 inch diameter dots varying slightly in arrangement as demanded by various experiments. In most of the experiments, however, the arrangement was as shown in Figure 2. The dot on the upper slide was located in the middle and one-quarter inch above the lower edge. The pair of dots above the red point (fixation point) was located in the middle of the lower slide and one-half inch from its upper edge. The second pair of dots was three-quarter inches directly below the upper pair. The centers of each pair of dots were separated by .155 inches. The red fixation point, .020 inches in diameter, was one-quarter inch below and midway between the upper pair of dots.

The inspection figure which was varied from experiment to experiment, was drawn in black India ink on an 8 X 8 inch piece of vinylite. This figure usually consisted of a line and fixation point and will be described before each experiment.

The height of the headrest was adjusted at the beginning of each experiment so that the subject's eyes were approximately at the same level as the fixation point. The figures were located 14 inches in front of the

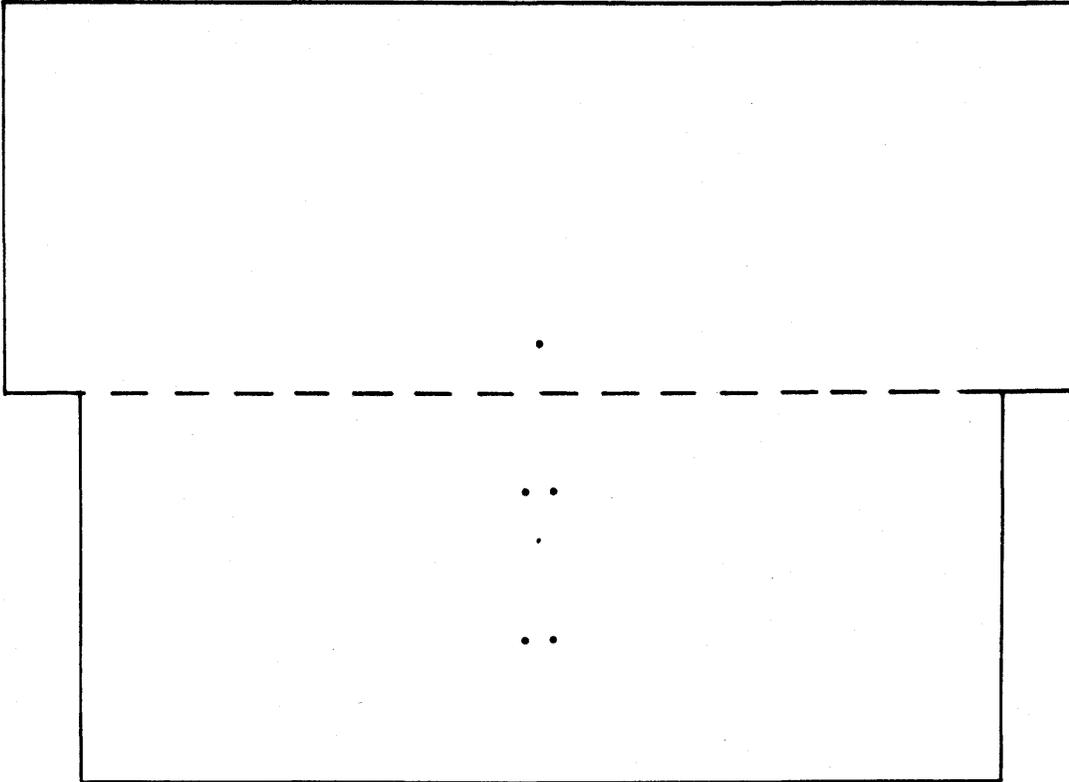


Figure 2. Schematic representation of the test figure (black dots) and fixation point (red dot). The lower section (slide) is stationary; the upper section is moveable.

subject's eyes. A five inch high elbow rest permitted the subject to stabilize his arm while turning the knob.

The figures were illuminated by a 500 watt floodlamp located 24 inches to the subject's left of the headrest and 31 inches from the figures. When the lamp was turned off the subject could see only the broad outline of objects in the room. A shield made of white paper was used to cover the figures as soon as the necessary judgment had been made.

## 2.2. Procedure

The subject's task in this study was to keep both eyes on the fixation point (red dot) and turn the knob until the upper moveable dot appeared to be in a straight line with the two lower stationary dots on the left of the fixation point when the moveable dot was offset to the left, or with the two dots on the right when offset to the right. He was instructed to say "now" as soon as the alignment was made, after which the experimenter covered the dots with the shield and switched off the lamp. Before each alignment was begun the upper dot was offset randomly between four to six complete turns (.200 to .300 inches) from perfect alignment. It was offset an equal number of times to the right and to the left, in random order.

The subject entered the testing cubicle and was asked to sit on a chair and place his head comfortably into the headrest. With the floodlamp on, the shield covering the test figure was removed, and the following instructions were given:

What I want you to do is keep your eyes on this red point (Experimenter pointed to the fixation point) and while you're looking at the red point turn this knob (upper dot was previously offset to subject's right) until this dot (Experimenter pointed to moveable dot) appears to fall in a straight line with the two stationary dots on the right of the red point. (Experimenter pointed to the two dots and demonstrated an alignment.) As soon as it appears to be lined up say "now" and keep your eyes on the red point until I cover the dots. When I throw the upper dot off to your left I want you to keep your eyes on the red point and turn the knob until the upper dot appears to be in a straight line with the two dots on the left (pointed to and demonstrated). (In these demonstrations the upper dot was never moved to perfect objective alignment.)

The important thing is to always keep your eyes on the red dot while you're turning the knob and say "now" as soon as the upper dot appears to be in a straight line with the appropriate lower dots. You must never look at the black dots.

When a subject did not understand what he was to do, the instructions were repeated.

The subject was then given a two minute rest during which he was allowed to take his head out of the headrest. With the upper dot offset either to the left or right, the subject was asked to put his head into the headrest and make the corresponding alignment. The subject made six such alignments, three with the moveable dot offset from the left and three from the right. Each alignment was separated by a one minute rest. The subject was required to make each alignment in a five to seven second period. If he turned the knob too quickly he was asked to slow up; if he turned too slowly, he was asked to speed up a little. Most subjects were able to make the judgment in five to seven seconds after approximately four alignments. While the subject made each alignment the experimenter watched his eyes

for movements. Whenever an eye movement was observed, the experimenter reminded the subject that he must not move his eyes from the red dot. He was told that when his eyes were on the red point the black dots were located in what is called peripheral vision, but when he looks right at the black dots they are then in central vision and will therefore be lined up differently. He was reminded that what we wanted him to do was always keep his eyes on the red point.

These six alignments permitted the subject to become familiar with the apparatus and were regarded as a practise session. Following two minutes of visual rest the subject made two more such alignments (separated by a one minute rest), one with the moveable dot offset to his right and one offset to his left. These two settings will be referred to as the Point of Subjective Equality (PSE) or control alignments. While the subject was having two minutes visual rest he was told that he would be asked to look at a red point on another card (inspection figure) for one minute. This card would then be removed and he would be required to look at the other red point and make another alignment. Two such alignments, each following the one minute exposure of the inspection figure, were made, one with the upper dot offset from the left and one from the right. These two settings will be referred to as the experimental alignments. Four minutes of visual rest was given after each experimental judgment. The session was continued with another two control and two experimental alignments, followed by two

more control and two experimental settings which ended the session.

In other words, each subject made six practise, six control and six experimental alignments. Each pair of control alignments was followed by a one minute rest after the first setting and a two minute rest after the second. Every experimental alignment was followed by a four minute rest. If the subject moved his eyes from the fixation point while making an alignment after the practise session, these data were excluded from the experiment. He was nevertheless required to remain in the cubicle making various alignments for the length of a complete 45 minute session.

The magnitude of the figural after-effect (displacement effect) is regarded as the difference between the mean control and mean experimental alignments. Usually two displacement effects were calculated: one from the difference between the three control and three experimental alignments made from the left for the left dots, and one from those made for the right dots. This provided the magnitude and direction of displacement for the left and right-hand test dots and when combined gave the amount of shrinkage or expansion of the test figure.

### 2.3. Subjects

All subjects tested in this study were university students ranging in age from 17 to 40 years. The mean age in each experiment was approximately 19 years. An equal number of male and female subjects was used across

experimental conditions. The students were not familiar with the purpose of the experiments, and each was tested only once. Subjects wearing contact lenses who found the illumination too bright were excluded from this study.

The students' timetable cards were first divided into male and female groups. Then, starting from the top of each group of cards, timetables were checked and subjects assigned to hours when both the student and experimenter were available. (During testing periods approximately 20 to 25 subjects were tested each week.)

The various conditions in each experiment were presented in counter-balanced order.

### CHAPTER III

### THE EXPERIMENTS

### 3.1. Experiment I

Before examining some of the predictions from Koehler's and Deutsch's theories, it must be determined how far satiation, or differential levels of excitability, extend from an I-figure under specified experimental conditions. According to Koehler's theory (Koehler & Wallach, 1944), when a figure is presented in the visual field, figure currents will flow around the corresponding area in the visual cortex. The area and pattern of this flow and resulting satiation will depend upon a number of variables. These include the shape of the inspection figure, degree of contrast between its contour and the ground, and the length of time the figure is inspected. Deutsch also points out that "How far each side of the previously excited locus we must go before underestimation due to enhanced excitability counteracts the overestimation caused by lessened activity, is difficult to predict, because of the statistical distribution of the initially excited locus due to small eye movements during fixation..." (1964, p. 21).

Therefore the purpose of this experiment is to determine the distance of the spread of satiation, or changed excitability, under given experimental conditions. This can be done by measuring the phenomenal displacement of a test point located at various distances from an inspection figure. In other words, the area affected by the inspection figure will

be determined and subsequent experiments will be concerned with displacement phenomena within this area.

### Procedure

Figure 3 shows the spatial relationship of four inspection lines to the test figure. The test figure consisted of an upper moveable dot drawn in the middle and one-quarter inch from the lower edge of the upper slide. The two lower black stationary dots were drawn in the middle of the bottom slide with the upper dot three-quarter inches from the upper edge, and the bottom dot one-half inch directly below its partner. Each black dot was .030 inches in diameter. The red fixation point, .020 inches in diameter, was located one-quarter inch above and one-eighth inch to the right of the upper stationary test dot.

The inspection figures consisted of four lines (1, 2, 3, 4 in Figure 3) with line 1 located one-quarter inch from the upper stationary T-dot, and each of the I-lines separated by one-quarter inch. The centers of the inspection lines were in the same horizontal plane as the upper stationary test point. Each inspection figure (one-quarter inch long and .030 inches wide) and correspondingly positioned red fixation mark was drawn on an 8 X 8 inch piece of white vinylite. When each of the four inspection cards was fitted directly in front of the T-figure with the red fixation points superimposed, the I-lines were positioned at the various distances from the T-figure as

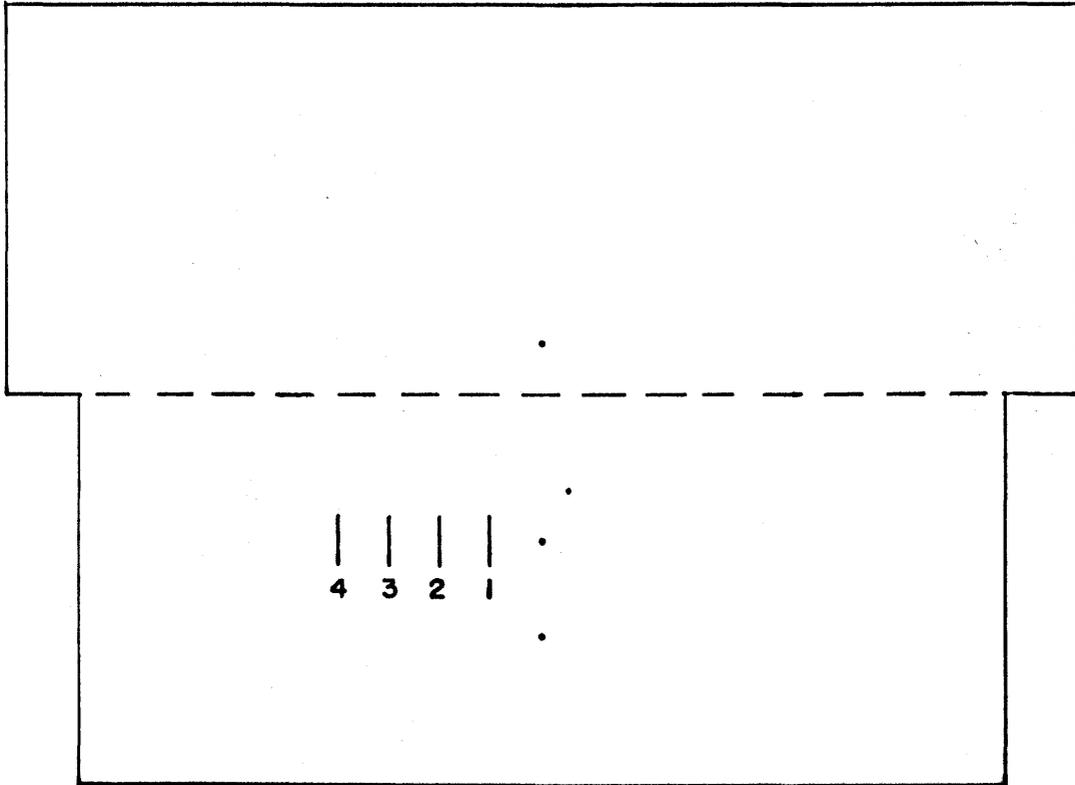


Figure 3. Schematic representation of four I-figure positions (1, 2, 3, 4), T-figure (black dots) and red fixation point. The lower section (slide) is stationary; the upper is moveable.

shown in Figure 3.

The procedure used to measure the magnitude of T-figure displacement was similar to that outlined in Chapter II. Following six practise alignments of the test figure, three with the upper dot offset from the left and three from the right, the subject was given a two minute rest. He then made another two settings, one from the left and one from the right, separated by a one minute rest which will be referred to as control alignments. Following a two minute rest, one of the four inspection cards was fitted in front of the T-figure and the subject looked at the red fixation point for one minute (inspection time). The card was removed and he made another alignment which will be called the experimental alignment. Every subject made four such experimental alignments with each of the four I-cards presented once, and separated by a three minute rest, except the fourth judgment which was followed by a five minute rest. Another two control and four experimental alignments, one for each I-card, terminated the session. In all, every subject made four control settings and eight experimental alignments, two for each of the four I-figure positions. An equal number were made with the moveable dot offset to the left and to the right.

Eighteen students served as subjects in this experiment. Since two of these subjects moved their eyes from the fixation point following the practise session, their figural after-effect was not measured.

## Results

The magnitude of test figure displacement was calculated by subtracting the mean of the two experimental settings for each of the four I-positions from the mean of the four control alignments. This yielded a figural after-effect for each of the four I- T-figure distances for every subject. The test point furthest from the I-line which showed consistent group displacement in one direction was regarded as the extent of the spread of satiation or differential levels of excitability. These data are shown in Table I where a negative value indicates displacement toward the I-line; no sign indicates displacement away from the I-figure.

A t test for related measures for each of the four inspection and test figure distances was calculated between the control and experimental means. These values are shown in Table I. The test figure was consistently displaced only following inspection of the I-line located one-quarter inch from the middle T-dot (15 df, p < .001). (There was no difference, t = 0.691, p = .50, between the magnitude of displacement when the upper dot was offset from the right compared with the displacement when aligned from the left.)

These results indicate that satiation or differential excitability affecting test figure displacement does not spread up to one-half inch from the I-line under the experimental conditions used in this study. Because

Table I

The Magnitude of Test Figure Displacement for the Four I- and T-figure Separations in Experiment I. Displacements are Expressed in Degrees with 7.2 Degrees Equal to .001 Inches. Negative Values Indicate Displacement toward the I-line; No Sign Indicates Displacement away from the I-figure.

I- and T-figure separation (Inches)				
Subjects	.250	.500	.750	1.000
1	152	103	- 47	-109
2	144	236	134	16
3	11	108	214	168
4	73	34	4	55
5	182	-132	181	-109
6	171	- 52	- 49	86
7	- 19	-239	-133	128
8	168	- 71	- 95	111
9	414	-222	129	6
10	- 51	- 11	- 68	49
11	255	125	164	6
12	257	253	-192	-100
13	156	-166	23	- 14
14	210	- 29	- 23	185
15	197	133	-177	-113
16	92	156	168	- 92
Mean:	151	14	15	17
S <sup>2</sup> :	13,161	23,846	18,006	10,322
t	5,254*	0.365	0.436	0.673

\*  $p < .001$

of these results displacement effects will be measured only within a distance of one-half inch from the inspection line in subsequent experiments.

### 3.2. Experiment II

It was stated in Chapter I (Sections 1.4 and 1.5, pp. 9-12) that according to Deutsch's theory (1964), when two test points are located on one side of an inspection line, one of these points will be displaced toward the I-figure and one away from it. Koehler and Wallach (1944), however, predict that both points must be displaced away from the inspection contour. Deutsch has also predicted that when two test points are located near a previously inspected I-line, in an area of decreased excitability, the apparent distance between them must increase. As the inspection figure is moved farther from the test points, the phenomenal distance between the points will gradually decrease until they are located in an area of increased excitability where the apparent distance must be the shortest (see Chapter I, Section 1.5, Figure 1). The purpose of this experiment is to test these predictions by measuring the apparent distance between two test dots as a function of their distance from an inspection line.

#### Procedure

The method of measuring figural displacement, and the test figure used in this experiment were the same as outlined in Chapter II of this report. Figure 4 shows four I-line positions (each position was separated by one-eighth of an inch) and their spatial relationship to the test figure. The test figure dimensions were the same as those described in the previous chapter. The red fixation point was one-quarter inch below and midway



Figure 4. Schematic representation of four I-line positions (1, 2, 3, 4), T-figure (black dots) and red fixation point in Experiment II.

between the upper pair of dots. Each inspection line and corresponding fixation point (same dimensions as in Experiment I) was drawn on an 8 X 8 inch piece of white vinylite. Inspection line 1 for example, was so positioned that when it was fitted in front of the test figure, it was superimposed on the left dot of the upper pair of test dots as shown in Figure 4.

The procedure was the same as outlined in Chapter II. That is, the subject first made six practise alignments: three with the two stationary dots on the left of the fixation point when the moveable dot was offset to the left, and three for the dots on the right when offset to the right. The subject then made two control judgments followed by two experimental alignments. (An experimental alignment consisted of a one minute inspection of one of the I-figures followed immediately by a test setting.) This was repeated twice, so that three control and three experimental judgments were each made for the left test dots when the moveable point was offset to the left, and three control and three experimental alignments for the dots to the right of the fixation point when the upper dot was offset to the right. Only one I-figure position was used in any one session.

Thirty-two subjects served in this experiment with eight in each of the four inspection line positions. Four subjects, however, refused or were unable to keep their eyes on the fixation point and were therefore excluded from this experiment. Four additional students were tested so

that a total of 36 subjects served in this experiment although only 32 were used: eight for each of the four inspection line positions.

### Results

For each subject the difference between the mean of the three control and mean of the three experimental alignments was calculated for the dots on the left and for the dots on the right of the fixation point. This provided the separate magnitudes of displacement for the left and right dots, and when combined indicated the amount of phenomenal shrinkage or expansion of the distance between the test dots.

Table II shows the phenomenal distance between the pair of test dots for each subject. Negative values indicate apparent shrinkage; no sign indicates expansion. Duncan's Range Test (McGuigan, 1960) showed that there was a significant increase in apparent expansion between I-line position 1 and position 3 ( $p < .01$ , 28 df), and a decrease from position 3 to 4 ( $p < .05$ ). (Fmax, used to test for homogeneity of variance, was not significant.)

An examination of each group's direction of displacement of the left and right test dots for each of the four I-line positions showed that the dot on the right was displaced away from the area previously occupied by the I-line, while the left dot was displaced toward the I-position. These data are shown in Table III where a minus value indicates displacement toward the I-figure and no sign indicates displacement away from the inspection positions.

Table II

The Phenomenal Distance of the T-dots for Each Subject in Experiment II. Negative Values Indicate Apparent Shrinkage; No Sign Indicates Expansion.

I-line positions			
1	2	3	4
- 55	365	310	- 49
-431	100	167	-181
136	279	257	284
115	269	245	223
148	203	407	264
237	160	293	184
81	140	509	122
350	294	296	33
Mean:			
73	226	311	110
S <sup>2</sup> :			
55,064	8,108	10,997	26,896

Table III

The Magnitudes of Displacement for Each Subject for the Left (L) and Right-hand (R) Test Dots in Experiment II. Negative Values Indicate Displacement Toward the I-figures; No Sign Indicates Displacement Away from the I-lines.

I-line positions							
1		2		3		4	
L	R	L	R	L	R	L	R
66	11	-318	47	- 40	270	139	90
149	-282	5	105	- 11	156	134	- 47
70	206	-193	86	- 6	251	-104	180
- 54	61	19	288	-116	129	- 16	207
-117	31	-159	44	-117	290	-184	80
- 81	156	- 56	104	- 32	261	- 34	150
-158	- 77	11	151	-129	380	- 48	74
-109	241	- 72	222	-179	117	-139	-106
<hr/>							
Mean:							
- 29	43	- 95	131	- 79	232	- 32	79

Combining the magnitudes of displacement of the right test dot in all four I-line positions (mean control compared with the mean experimental alignment) showed that this dot was significantly displaced away from the I-line positions ( $t=5.131$ , 31 df,  $p < .001$ ). A similar analysis of the left dot, excluding I-position 1 since the dot was coincident with this I-line, showed that it was displaced toward the I-figures ( $t=3.262$ , 23 df,  $p < .01$ ).

### Discussion

As pointed out earlier, Deutsch has predicted that when two test points are located in an area of decreased excitability near a previously inspected I-line, the apparent distance between the points will increase. As the points are moved away from the I-figure into higher levels of excitability the phenomenal distance between these points will decrease. The results of Experiment II show a trend in the opposite direction to that predicted by Deutsch. That is, the phenomenal distance between the test points increased as they were positioned farther from the I-line. Also, the maximum phenomenal expansion at some distance from the I-figure (Position 3) and subsequent reduction in apparent distance further from the I-line (Position 4) are contrary to Deutsch's theory. According to Deutsch's model, phenomenal expansion will be greatest at the inspection contour and decrease as test points are moved away from the I-figure.

The results of Experiment II confirm Deutsch's prediction that one of two test points will be displaced toward the I-line, and one will be displaced

away from it. As the above discussion indicates, however, the directions of these displacements do not all conform to the theoretical predictions. As the test points move into higher levels of excitability (farther from the I-line) they must, according to Deutsch's theory, be displaced toward each other, not away from each other as observed in this experiment.

It was also mentioned earlier that according to Koehler and Wallach's theory all the test points in Experiment II, except the left test dot in I-position I (where it is superimposed on the I-line), must be displaced away from the I-lines. The results of Experiment II, however, showed that only the right-hand dot of the test figure was displaced away from the I-lines in the combined inspection conditions, while the left dot in three inspection positions was displaced toward the I-figures. Although Koehler and Wallach have admitted that a T-figure may be displaced toward an I-figure, they have not explained how this is possible in terms of their hypothesized figure currents. Furthermore, they claim this is possible only when the T-figure is "...just adjacent..." to the I-figure (1944, p. 297). In Experiment II the test dots were at considerable distances from the inspection line, and must, according to their theory, be displaced into areas of lesser satiation, that is, away from the I-line. These results also confirm earlier reports of displacement toward an I-figure (Kelm, 1962; Kelm, Jensen & Ramsay, 1963; Nozawa, 1953; Prysiazniuk & Kelm, 1963, 1965; Smith, 1954).

In summary, the results of Experiment II are opposite in direction to the predictions of Deutsch's theory, and the displacement toward the I-figure cannot, at present, be explained by Koehler and Wallach's satiation theory.

### 3.3. Experiment III

Figure 1 (Chapter I, Section 1.5) shows that according to Deutsch's theory "Depression of excitability occurs maximally at the locus which had been excited by the point of a contour of the inspection figure" (1964, p. 21). Therefore the apparent expansion of the distance between two test points following inspection of an I-line passing through these points must be maximal (see Figure 5, Condition 1). The level of excitability between two test points will also be decreased following inspection of a line midway between and perpendicular to these points (see Figure 5, Condition 2). However, the level will not be depressed as much as in Condition 1. Therefore, the apparent expansion of the distance between the points in Condition 1 must, according to Deutsch's theory, be greater than in Condition 2. The purpose of this experiment was to test this prediction.

#### Procedure

Figure 5 shows the two experimental conditions used in this experiment. The inspection and test figure dimensions were the same as in Experiment II. In Condition 1 the I-line passed through the T-dots so that it extended approximately one-sixteenth of an inch beyond each dot. In Condition 2 the I-line was midway between the two T-dots. (The same test figure was used in both conditions.) Each of the two inspection figures was drawn on an 8 X 8 inch piece of white vinylite. When fitted in front of the

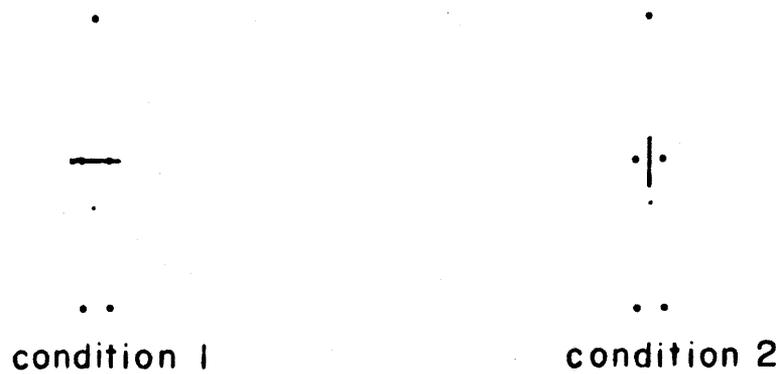


Figure 5. Spatial relationships between two identical test figures (black dots) and two inspection conditions (black lines) in Experiment III. The red dots are the fixation points.

T-figure with their fixation points superimposed, the I- T-figure relationships were as shown in Figure 5. The inspection time and method of measuring the apparent distance between the test dots was the same as in Experiment II.

Only one experimental condition was used in any one session. Eighteen subjects served in this experiment with nine in each condition. Four students did not keep their eyes on the fixation point and were therefore replaced by four additional subjects.

### Results

The difference between the mean of the six control and mean of the six experimental alignments was calculated for each subject. This provided the magnitude of phenomenal shrinkage or expansion of the distance between the test points. These data are shown in Table IV. The group means showed that there was an increase in apparent distance under both experimental conditions compared with the control conditions. The phenomenal expansion in Condition 2, however, was significantly greater than the expansion in Condition 1 ( $t=2.824$ , 16 df,  $p<.02$ ).

### Discussion

As stated above, the apparent expansion of the distance between the points in Condition 1 must, according to Deutsch's theory, be greater than in Condition 2. The results of this experiment, however, show that the

Table IV

The Phenomenal Expansion of the Distance between the T-dots for Each Subject in Experiment III. The Negative Value Indicates Apparent Shrinkage; No Sign Indicates Expansion.

Conditions	
1	2
366	442
352	227
85	234
285	487
- 4	361
141	216
87	360
139	309
19	267
Mean:	
163	323
S <sup>2</sup> :	
19,170	9,473

phenomenal distance was greater in Condition 2 than in Condition 1. Again, the experimental results are contrary to Deutsch's predictions.

No definite predictions of phenomenal distance can be made from Koehler and Wallach's theory in the above conditions. In Condition 2 there must be a phenomenal increase in the distance between the two affected test dots since the level of satiation is higher between the dots than it is beyond them. In Condition 1, however, differences in the levels of satiation between and beyond the two test dots depend upon the length of the inspection line. Since this line extends only approximately one-sixteenth of an inch beyond each T-dot, it does not seem possible to estimate the difference in the levels of satiation between and beyond the test points. Therefore a prediction concerning the phenomenal distance between these points is not warranted. A theoretical prediction of apparent distance may be made however, if the I-line in Condition 1 is lengthened.

### 3.4. Experiment IV

The purpose of this experiment was to lengthen the I-line in Condition I of Experiment III so that a definite prediction of phenomenal distance between two test points could be made from the satiation theory, (see Figure 6).

When the I-line is extended so that satiation, following inspection of this line, will be the same between and beyond two test points (Koehler and Wallach have referred to this situation as homogeneous satiation), the phenomenal distance between these test points will be shorter than the distance between them when in a neutral or unsatiated region (control condition).

"In a homogeneously and strongly satiated area not much further satiation can occur; but the distance between two comparison objects in a neutral area would be increased by that factor, inasmuch as immediate satiation of the area between these objects would be greater than satiation beyond the objects" (Koehler & Wallach, 1944, p. 356). (See Chapter I, Section 1.5 and Chapter IV for a more detailed account.)

According to Deutsch's theory (see Figure 1, Chapter I, Section 1.5 and Experiment III), the decrease in excitability will be maximal in the condition shown in Figure 6. Therefore the apparent distance between the test points must be greater than the distance between these points in an area of normal excitability (control condition). In other words, the satiation theory predicts that the phenomenal distance between two test points in the above

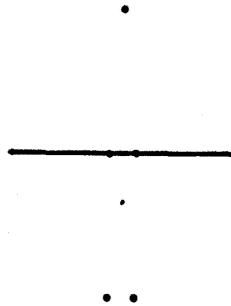


Figure 6. Spatial relationship between the test figure (black dots) and inspection line (black line) in Experiment IV. The red dot is the fixation point.

condition (Figure 6) must be shorter than the control distance, while Deutsch's theory maintains that the apparent distance must be greater than in the control situation. Also, according to Deutsch's position the level of excitability between the two test points must be the same in Condition 1 of Experiment III as in this experiment (Figure 6) since both were "...excited by the point of a contour of the inspection figure" (Deutsch, 1964, p. 21). Therefore, the phenomenal distance between the test points in these two conditions must be the same. The purpose of this experiment was to test these predictions.

#### Procedure

Figure 6 shows the inspection and test figure relationship used in this experiment. The experimental conditions were the same as in Experiment III except that the I-line was lengthened so that it extended one-half inch beyond each T-dot.

The method of measuring the apparent distance between the test dots was the same as in Experiment III. Two of the fourteen students serving as subjects were excluded from this experiment when they were unwilling or unable to maintain constant fixation on the red dot.

#### Results

As in Experiment III, the difference between the mean of the six control and six experimental alignments was calculated for each subject. This provided the magnitude of phenomenal shrinkage or expansion of the distance

between the test dots. These data are shown in Table V, where a negative value indicates an apparent distance shorter than in the control condition; no sign indicates phenomenal expansion. A comparison between the experimental and control alignments showed that the phenomenal distance between the test points was shorter following inspection of the I-line than in the control condition. This difference, however, was not statistically significant ( $t=2.079$ , 11 df,  $p < .10 > .05$ ). Also the apparent distance between the test points in Condition 1 of Experiment III was greater than the distance between these points in this experiment ( $t=3.831$ , 19 df,  $p < .01$ ).

### Discussion

Since the experimental and control judgments were not significantly different, no conclusions regarding the above theoretical predictions seem warranted. It may be noted, however, that the apparent distance between the test points following inspection of the I-line was shorter than the control distance as predicted by the satiation theory. Further investigation of this experimental condition is indicated.

As was stated above, the level of excitability and thus the apparent distance between the test dots in Condition 1 of Experiment III and in this experiment (see Figure 6) must, according to Deutsch's theory, be the same. It was found, however, that the phenomenal distance between the test points was greater in Condition 1 of Experiment III than in this experiment. This

Table V

The Phenomenal Distance between the T-dots for Each Subject in Experiment IV. Negative Values Indicate an Apparent Distance Shorter Than the Control; No Sign Indicates Expansion.

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187
-201
-371
204
-296
-142
-110
-459
- 95
31
- 50
- 145

---

Mean: - 121

$s^2$ : 40,383

---

finding would suggest that Deutsch's theory should consider not only the level of excitability between two points, but also the level of excitability beyond them. Further research into this possibility seems indicated.

### 3.5. Experiment V

In Chapter I, Section 1.5 it was stated that one of the problems confronting the satiation theory occurs when two test lines parallel to each other and at right angles to a previously inspected line appear closer together than two similar test lines further from the inspection line. This situation is shown in Figure 7 using dots instead of parallel lines for the test figure. In order to explain this phenomenon Koehler and Wallach (1944) introduced the hypothesis of immediate self-satiation which Hebb (1949) regarded as ad hoc.

According to Koehler and Wallach (1944), satiation will develop more quickly in the interior of a circumscribed figure than in its exterior. Therefore, the phenomenal size of the figure must increase, since contours are always displaced from areas of greater to lesser satiation. In the above situation the apparent distance between the two test lines or dots nearest the I-line will not be changed by immediate self-satiation because they lie in a highly homogeneously satiated region where little or no additional satiation can take place (Koehler & Wallach, 1944, p. 356). The phenomenal distance between the test points located further from the I-line, however, will be increased since they lie in a relatively unsatiated area, thus permitting satiation to develop more quickly between than beyond them.

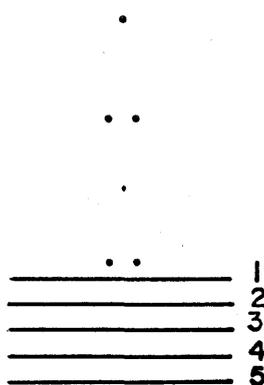


Figure 7. Spatial relationship between the test figure (black dots) and inspection lines. I-lines 1, 2 and 3 were used in Experiment V and lines 4 and 5 were employed in Experiment VI. The red dot is the fixation point.

Deutsch (1964) has stated that this situation offers no difficulty for his theory since the level of excitability between the test figures nearest the I-line is higher than the level between the test points further from the I-figure. Therefore, the apparent distance between the test points nearest the inspection figure must be shorter than those further from the I-line.

Koehler and Wallach have suggested that final judgment on the hypothesis of immediate self-satiation in homogeneously satiated regions must wait upon experimental evidence (1944, pp. 356-357). With the exception of Koehler and Wallach's original report, this aspect of the satiation theory seems never to have been investigated. Therefore, the purpose of this experiment was to measure the predicted effects of self-satiation in terms of the apparent distance between test points in homogeneously satiated and unsatiated areas.

#### Procedure

The inspection and test figures were the same as in Experiment IV except that the two stationary pairs of dots were drawn one-quarter inch higher on the bottom slide. Also, the red fixation point was drawn midway between the two pairs of T-dots. The relationship between the inspection and test figures is shown in Figure 7. It will be noted that in previous experiments the I-figure was in the area of the upper pair of T-dots, whereas in this experiment the inspection lines were in the region of the lower pair

of test dots. Three I-line positions, 1, 2 and 3 were used in this experiment. (Inspection lines 4 and 5 were employed in Experiment VI and will be discussed later.) I-line 1 was one-sixteenth of an inch below the lower pair of T-dots, and each inspection line was separated by one-eighth of an inch. This figure is a variation of Koehler and Wallach's original Figures 18, 19 and 20 in which self-satiation effects in homogeneously satiated regions were first observed (1944, p. 280). As in previous experiments each I-figure and corresponding fixation point was drawn on a separate card.

The inspection time and method of measuring the apparent distance between the test dots were the same as in Experiment IV. Only one I-line position was used in any one session. Twenty-seven subjects served in this experiment with nine in each condition. Four students did not keep their eyes on the fixation point and were therefore replaced by four additional subjects.

### Results

As in the previous experiments, the difference between the mean of the six control and the six experimental alignments was regarded as the phenomenal distance between the affected (lower) test dots. The apparent distance between the T-dots following inspection of each of the three I-line positions is shown in Table VI. A negative value indicates an apparent distance shorter than in the control condition; no sign indicates expansion.

Table VI

The Magnitude of Phenomenal Distance between the Test Points for Each Subject in Experiment V. Negative Values Indicate a Distance Shorter Than in the Control Condition; No Sign Indicates Expansion.

I-line positions		
1	2	3
- 56	-41 6	- 25
- 531	- 81	- 111
-267	97	-146
- 85	5	122
-350	-106	84
-192	-144	138
-105	-167	73
-102	182	58
- 58	23	-322
Mean:		
-194	- 67	- 14
S <sup>2</sup> :		
26,131	30,20 3	23,222

Duncan's Range Test showed that the phenomenal distance between the T-points nearest the I-line (I-line 1) was shorter than the points furthest from the inspection figure (I-line 3;  $p < .05$ ). Also, the apparent distance between the points was shorter following the inspection of line 1 than in the control condition ( $t=3.599$ , 8 df,  $p < .01$ ).

### Discussion

The results of this experiment are similar to those first reported by Koehler and Wallach (1944, pp. 280-281). They confirm the theoretical predictions of both Deutsch and Koehler and Wallach by showing that the phenomenal distance between two points located near a previously inspected contour, and parallel to it, is shorter than the distance between the same points situated further from this contour. These results also show that the apparent distance between such test points near an inspection figure is shorter than the distance between these points located in an unsatiated area or region of normal excitability (control condition). As stated above, both theories seem to predict such an observation.

### 3.6. Experiment VI

Since the apparent distance between two points as a function of the level of homogeneous satiation seems never to have been systematically investigated, it was decided to extend the I- T-distances of Experiment V. Therefore the purpose of this experiment was to measure the phenomenal distance between the two test points located at greater distances from the I-line than in Experiment V.

#### Procedure

Two inspection conditions, lines 4 and 5 as shown in Figure 7, were used. Inspection lines 4 and 5 were located one-eighth and one-quarter inch, respectively, below the I-line 3 position of Experiment V.

The test figure, inspection time and method of measuring the apparent distance between the test points was the same as in Experiment V. Only one I-line position was used in any one session. Eighteen subjects meeting the criterion of fixation on the red dot served in this experiment with nine in each condition. (Eight students did not meet the criterion of fixation.)

#### Results

The magnitude of phenomenal distance between the test dots was calculated in the same way as in Experiment V. The apparent distance following inspection of lines 4 and 5 is shown in Table VII. A negative value indicates a distance shorter than in the control condition; no sign indicates expansion. The phenomenal distance between the test points was not significantly greater

Table VII

The Magnitude of Phenomenal Distance between the Test Points for Each Subject in Experiment VI. Negative Values Indicate a Distance Shorter Than in the Control Condition; No Sign Indicates Expansion.

I-line positions	
4	5
113	73
277	242
7	81
-133	288
6	24
131	102
432	-153
98	251
52	- 29
Mean:	
109	98
S <sup>2</sup> :	
27,000	20,723

following inspection of lines 4 or 5 than in the corresponding control conditions ( $t=1.989$  and  $2.042$ , respectively,  $p > .05$ ). However, combining these two inspection conditions showed that the apparent distance between the points, following inspection of I-lines 4 or 5, was significantly greater than the distance in the control condition ( $t=2.929$ ,  $17$  df,  $p < .01$ ).

### Discussion

According to Deutsch's theory (see Chapter I, Section 1.5, and Figure 1) it is only possible to observe an increase in apparent distance between two points, compared with a control observation in an area of normal excitability, at or immediately around the locus of a previously inspected line which is in a lower than normal state of excitability. At a greater distance from the I-line there will be a region in which excitability is higher than normal and therefore phenomenal distance must be less than in the control condition. The area beyond this region of increased excitability will be in a state of normal excitation and therefore apparent distance will be the same as in the control condition. In other words, once there is a maximum phenomenal decrease in distance as in I-condition 1 of Experiment V, apparent size must increase with increasing distance between the I- and T-figures until it reaches the size of the figure in the control condition. There cannot, according to Deutsch's theory, be an increase in phenomenal size as observed in Experiment VI.

According to Koehler and Wallach's theory the distance between two points in a homogeneously satiated region must be shorter than that of similar points in an unsatiated area (1944, p. 356). Since satiation is strongest at the point previously occupied by the I-line and decreases with distance from this area, phenomenal size will be smallest at the I-line and increase with increasing distance from the inspection contour until the distance between the test points is the same as in the control condition. The apparent distance between the points, according to Koehler and Wallach's theory, cannot be greater than that in the control condition as was observed in this experiment.

### 3.7. Experiment VII

Koehler and Wallach have stated that the distance between two objects in a strongly and homogeneously satiated region "...fails to grow under the influence of immediate self-satiation. In a homogeneously and strongly satiated area not much further satiation can occur; but the distance between two comparison objects in a neutral area would be increased by that factor, inasmuch as immediate satiation of the area between these objects would be greater than satiation beyond the objects" (1944, p. 356). This suggests that the distance between the test points in the control conditions of Experiment V and VI (as well as in the other experiments of this study, except Experiment I) must have been increased by self-satiation. It also suggests that what is regarded as the full size of a visual object is actually a size that is partially due to immediate self-satiation (Koehler, 1960, personal communication).

Deutsch's theory it seems does not permit a prediction in this situation.

The purpose of this experiment was to test Koehler and Wallach's prediction by measuring the absolute location of a single dot compared with the position of a pair of dots as used in the above experiments. In the case of a single dot satiation will develop symmetrically about this point so that no displacement can occur (Koehler & Wallach, 1944, p. 337). Between two



Figure 8. Two test figure conditions (black dots) used in Experiment VII. The red dots are the fixation points.

left and three from the right. Following a five minute rest each subject made another six such alignments with the other test figure.

### Results and Discussion

The difference between the means of the six alignments in each of Conditions 1 and 2 for every subject was regarded as the magnitude of displacement of the left dot in Condition 2. These data are shown in Table VIII where a negative value indicates displacement to a subject's right; no sign indicates displacement to the left. The results showed that the left dot of test figure 2 was displaced to the subjects' left as compared with the position of the single dot in test figure 1 ( $t=3.589$ , 7 df,  $p < .01$ ). These results therefore confirm Koehler and Wallach's hypothesized effect of self-satiation.

Table VIII

The Magnitude of Displacement of the Left Dot in Condition 2 for Each Subject in Experiment VII. A Negative Value Indicates Displacement to Subject's Right; No Sign Indicates the Predicted Displacement to Subject's Left.

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154
91
90
112
- 31
298
79
143

---

Mean: 117
$s^2$ : 8,512

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**CHAPTER IV**

**GENERAL DISCUSSION**

#### 4.1. The Results and Deutsch's Theory

The experimental findings of this investigation offer considerable difficulty for Deutsch's theory. Experiment II showed that as two test points were moved from an inspection line, the phenomenal distance between them increased. According to Deutsch's model the apparent distance between two points must be greatest at and immediately around an inspection figure and decrease with increasing separation of the I- and T-figures.

In Experiment III it was found that the phenomenal distance between two points, following inspection of a horizontal line that passed through these points, was shorter than when a vertical I-line was located midway between the points. Again this is contrary to Deutsch's theory which must predict that the apparent distance in the former condition should be greater than in the latter situation. When the I-line passing through the test points of Experiment III was lengthened in Experiment IV, there was a slight but not quite statistically significant shrinkage in distance between the test points (relative to the control condition). Deutsch must in this situation expect an increase in phenomenal distance.

Deutsch's theory also states that the apparent distance between two test points lying parallel to and near an I-line must be shorter than the distance between similar points in the control condition (normal excitability).

This was confirmed in Experiment V. With increasing separation of inspection and test figures, the phenomenal distance between the test points must, according to this model, return to the distance in the control condition. Experiment VI, however, showed an increase in apparent distance relative to the control.

Briefly, most of the results of the above experiments not only fail to confirm Deutsch's theory, but tend to be in a direction opposite to some of the predictions from this model.

#### 4.2. The Results and Koehler's Theory

All of the above results confirm Koehler's theory except the displacement of the test point toward the inspection figure in Experiment II, and the increase in phenomenal distance as observed in Experiment VI. An attempt will now be made to explain these and similar results (Kelm, 1962; Kelm, Jensen & Ramsay, 1963; Nozawa, 1953; Prysiazniuk & Kelm, 1963, 1965; Smith, 1954) within the framework of the satiation theory.

When a circumscribed figure such as a circle or even two dots is exposed in the visual field, satiation will initially develop more quickly within or between these two points than beyond them (Koehler, personal communication, 1960; Koehler, 1965; Koehler & Wallach, 1944, p. 356). This will increase the distance between the two dots, since points or contours are always displaced from areas of greater to lesser satiation. (Koehler

has called this initial growth immediate self-satiation and it will hereafter be referred to as the stage of maximum growth, or Stage 1.) With continued inspection of this figure, however, the distribution of satiation (inside stronger than outside) will gradually change. That is, since satiation is greater inside than outside the figure, this very fact will soon reduce the figure currents between the two dots, and beyond these dots the flow will as a consequence be increased (Koehler, personal communication, 1960; Koehler, 1965). As this happens the phenomenal distance between the points will now become smaller (Stage 2) than it was in its maximum growth stage.

The crucial question in this discussion is how long it takes a figure to reach the first stage of maximum growth and then show a gradual reduction in size (Stage 2). Koehler has recently suggested that this first stage may be reached within a fraction of a second (1965, p. 70). Winters has shown that under tachistoscopic conditions a circle expands within 0.2 seconds of exposure and beyond this time it "...contracts toward its normal size" (1964, p. 821). In the case of a circle, for example (the same will also apply to the distance between the two dots used in the above experiments), it "...should expand before our eyes when it is just appearing. But, if the satiation of its interior occurs so fast, the redistribution of its current toward the outside, and therefore also the corresponding increase of satiation outside,

must also begin quite early - with the consequence that, after having reached maximal size in a few moments, the circle will now begin to look smaller" (Koehler, 1965, p. 70).

At this point one assumption will be made that appears to follow from the satiation theory.

Koehler and Wallach have shown that when two black and two identical light grey squares are exposed in the visual field, "...the distance between the black squares was at first sight greater than that between the grey squares..." (1944, p. 356). "...since the figure currents of the black squares must be much stronger than those of the pale squares, satiation would enlarge the distance between the former immediately, while this effect would be delayed in the case of the latter" (1944, pp. 356-357). This suggests that when figure currents are weak the phenomenal increase in distance between two points will be delayed relative to the effect of stronger figure currents. Since Koehler and Wallach have stated that figure currents in a satiated area must be weakened (1944, p. 356); it will now be assumed that the maximum growth of a circle, or distance between two dots (Stage 1), and subsequent reduction in distance with continued inspection (Stage 2), will be delayed in a satiated region, and that the length of this delay will be a function of the level and pattern of the pre-existing (I-figure) and T-figure satiation.

Using this assumption, an attempt will now be made to explain displacement of a test contour toward an inspection figure (Experiment II; Kelm, 1962; Kelm, Jensen & Ramsay, 1963; Nozawa, 1953; Prysiazniuk & Kelm, 1963, 1965; Smith, 1954), and the increase in phenomenal distance in Experiment VI, which at present appear to be contrary to the predictions from the satiation theory.

In Experiment II it was shown, contrary to the satiation theory, that when a test dot was compared with the position in the control condition it was phenomenally displaced toward the I-line. (This discussion will be restricted to the left dot used in the above experiment since it was this point that was displaced toward the I-figure. A similar explanation may be used for the right-hand dot.) Since the two dots in the control condition are in a relatively unsatiated region, satiation will immediately increase the distance between them (Stage I). That is, the left point will be displaced to a subject's left. With continued inspection the pattern of satiation will change (see above explanation) so that the left dot will begin to return toward its objective position (its position before immediate self-satiation takes place) before a subject has made the necessary judgment. It must also be pointed out that while this dot is gradually returning toward its objective position, it will be heavily satiating the region through which it is passing (satiation is always greatest at the locus of a contour), thus further increasing its displacement in this direction. When a subject makes his

judgment (in the above experiments an alignment was completed in approximately 6 seconds) the dot will presumably be approaching its objective position.

Following inspection of the I-line, the test figure currents will be deflected away from the position of the I-line (Koehler & Wallach, 1944, pp. 336-337) and therefore the T-dot will initially appear displaced away from the region previously occupied by the inspection figure. This is due to the fact that the level of satiation is higher between the left T-dot and the I-line (area A in Figure 9) than it is between the two T-dots (area B). However, this distribution of satiation will be immediately changing, with satiation developing at a faster rate in area B than in A. This must be the case since the level of satiation is lower in area B than in region A. Also, area B will be pervaded by the figure currents of the two test dots while region A will be satiated only by the left T-dot. Parenthetically it may be mentioned that the rate of increase in the level of satiation in region B will also depend upon the distance between the two T-dots.

This must result in the gradual displacement of the left dot toward the inspection contour. Since this point is located in a satiated region, this displacement, as pointed out earlier, will be delayed relative to the movement in the control condition. Also, the gradual movement of the T-dot toward the I-line will be heavily satiating the region through which it is

| A.B.

Figure 9. Spatial relationship between the inspection figure (line) and a test object (two dots) in Experiment II. A represents the area between the I- and T-figures; B is the area between the two T-dots.

passing, thus further increasing its displacement toward the inspection line. Since the subject requires a certain period of time to make an alignment, it is assumed that when the judgment is made the T-point will be nearer the above maximum growth position (Stage 1) than it was in the control condition. Therefore this dot in the experimental condition, relative to the control position, will appear closer to the I-line or displaced toward it.

It can be seen from the above explanation that the magnitude and direction of displacement will depend upon a number of variables. Since the test figure is changing the pattern of satiation established by the inspection figure, the rate of this change must be governed by the pattern and level of satiation produced by the I-object and the relative effect of the T-object. Therefore, variables such as the lengths of the inspection and test times, the shapes, brightness and sizes of both figures, as well as their spatial separation must determine the magnitude and direction of T-figure displacement.

The above explanation may also be applied to Smith's (1954) reported test object displacement toward an inspection figure. He found that a small test square located near an I-oblong was displaced toward the I-figure, as was the left dot in Experiment II.

A similar explanation may be offered for the apparent displacement of a curved test line toward a less curved inspection line (Nozawa, 1953). When the curved T-line is presented in the control condition, satiation will

immediately decrease its curvature to a maximum point (Stage 1), since satiation will initially develop more quickly within the curved area than on the opposite side. With continued inspection the rate of satiation will decrease within the curve and increase on the opposite side, resulting in increased curvature from Stage 1. In other words, when a subject makes the control judgment, the curvature will be considerably more than it was in Stage 1. Following inspection of the I-line, the above process will be delayed so that when the experimental judgment is made the curvature will be closer to the Stage 1 position than in the control judgment. Therefore the curvature in the experimental condition will be less than in the control situation, so the former will appear displaced toward the I-contour.

The above account may also be applied to the displacement of a test figure toward an inspection line reported by Kelm (1962), Kelm, Jensen and Ramsay (1963) and Prysiazniuk and Kelm (1963, 1965). These investigators found that immediately after inspection of an I-line, a T-line, relative to the control judgment, was displaced away from the inspection contour. When the T-line was repeatedly exposed in the visual field or even inspected, displacement decreased and eventually, relative to the control, was displaced toward the I-line. They also observed that when inspection time of the I-line was increased, inspection of the T-line must also be increased if displacement of the latter toward the former is to occur. In other words, when the pattern

of satiation produced by the I-line was strengthened, the satiating effect of the T-figure must correspondingly be increased in order for the latter to be displaced toward the former.

It seems that the above explanation of displacement toward an inspection figure may be applied to these results. Figure 10 represents a simplified version of the I- and T-lines used by these investigators. When the T-figure is presented in the control condition it will not be displaced as were the T-objects in the studies cited earlier (Experiment II; Nozawa, 1953; Smith, 1954). This is due to the fact that satiation will develop symmetrically around the T-line so that no displacement is possible. Following inspection of the I-line, the figure currents of the T-line must be deflected away from the former, since the level of satiation is higher in area A than in region B. Therefore, immediately after inspection the T-line will appear displaced away from the I-line. However, the pattern of satiation established by the inspection figure will also begin to change. That is, satiation will develop more rapidly in B than in A, with the result that the T-line will begin to move back gradually toward the I-line. It might also be mentioned that this gradual movement toward the I-contour will be slower in this situation than it was in Experiment II since area B in Experiment II was satiated by two test points.

While the T-line is moving toward the I-line it will also be heavily



Figure 10. A simplified schematic representation of the I- (dashed line) and T- (solid line) figures used by Kelm (1962), and Prysiazniuk and Kelm (1963, 1965). The area between the I- and T-lines is represented by A; B refers to the region beyond the T-contour.

satiating the region through which it is passing. This high level of satiation, as well as the increasing level in area B, must eventually result in their reported displacement toward the inspection figure. The fact that the direction of displacement depended upon the relative length of their inspection and test times offers, of course, no difficulty.

How may the above explanation be applied to the results of Experiments V and VI? First of all it must be pointed out that following inspection of the I-line, the pattern of satiation established by this I-figure will, with respect to the orientation of the T-dots, be different than in Experiment II. In Experiment II the two test dots were at right angles to the I-line and were therefore situated in what may be referred to as gradient satiation. That is, the level of satiation must be higher in area A (Figure 9) than in region B, and higher in B than beyond the right-hand dot. As pointed out earlier, this will result in the deflection of the test currents away from the I-line. This, however, will not be the case in Experiment V and VI.

In Experiments V and VI the two test dots were parallel to the I-line and were therefore situated in what Koehler and Wallach (1944) have called homogeneous satiation. That is, the level of satiation immediately following inspection of the I-line will be the same between the two dots as it is beyond them. This I-figure pattern of satiation alone will not result in immediate displacement of the T-figure, since displacements occur only from areas of greater to lesser satiation.

As stated earlier, when a subject makes a judgment in the control condition both T-dots will have moved from the maximum growth position (Stage 1) and will be approaching their objective position (Stage 2). When the two test points are placed in a highly satiated region such as Condition 1 of Experiment V, little or no further satiation can take place, with the result that there will be little or no change from the objective distance between the dots. Therefore the distance between the points in this strongly satiated region will appear shorter than the distance in the control condition. This was observed in Experiment V, Condition 1, and was reported by Koehler and Wallach (1944, p. 280).

As these two test points are moved further from the I-line into lower levels of satiation, the distance between them will increase and approach the size in the control condition. This was noted in Condition 3 of Experiment V. In other words, when the test points are placed into less satiated areas, more satiation from the test figure can take place. This will increase the distance relative to the size in the highly satiated region, and consequently approach the size in the control condition.

As the test dots are moved further from the I-line, a level of satiation will be reached in which the maximum growth (Stage 1) will be delayed to the point where it coincides with the time when a subject completes the necessary judgment. The phenomenal distance will therefore be greater than it was in the control condition. This presumably was the case in Experiment VI.

Briefly, in an unsatiated area such as in the control condition, satiation will develop rapidly so that when a subject makes the judgment the phenomenal distance will be less than the maximum growth of Stage 1. In a satiated region this initial maximum growth and subsequent reduction in size will be delayed, and the length of this delay will depend upon the level of satiation. In a highly and homogeneously satiated region little or no additional satiation can take place, so the distance must be shorter than in an unsatiated area (Condition 1 of Experiment V). At a certain lower level of satiation further from the I-line, the process of growth will be delayed so that when a subject makes the judgment, the distance between the points will be at or closer to the maximum growth stage than in the control condition. Therefore the distance between the points will appear greater than in the control condition (Experiment VI). At an intermediate level of satiation the phenomenal distance must be similar to that in the control situation (Conditions 2 and 3 of Experiment V).

The results of Experiment VII, of course, offer no difficulty.

**CHAPTER V****EXPERIMENT VIII**

### Experiment VIII

In Experiment II it was found that when two test points separated by one-eighth of an inch were at right angles to an inspection line, the point nearest the I-line was displaced toward it. Since the magnitude and direction of displacement are partially dependent upon the satiating effect of the test figure (Chapter IV, Section 4.2), then increasing the distance between the two T-dots under the conditions of Experiment II must affect test figure displacement. The purpose of this experiment was to test this prediction.

#### Procedure

Figure 11 shows an inspection line for each of three test figures used in this experiment. The pair of test dots were separated by one-eighth, three-eighths and one inch in T-figures 1, 2 and 3, respectively. The diameter of the T-dots, their vertical separation and position of the fixation point were the same as in Experiments V and VI. Since the left test dot in Experiment II was significantly displaced toward the I-line in Condition 3 ( $p < .02$ ), this position was used in this experiment. That is, the inspection line was located one-quarter inch from the pair of test dots in each figure (see Figure 11). It will also be noted that in the experiments of Chapter III the room in which the experiments were conducted was semidark during the subject's rest periods. In this experiment a 40 watt fluorescent room light was

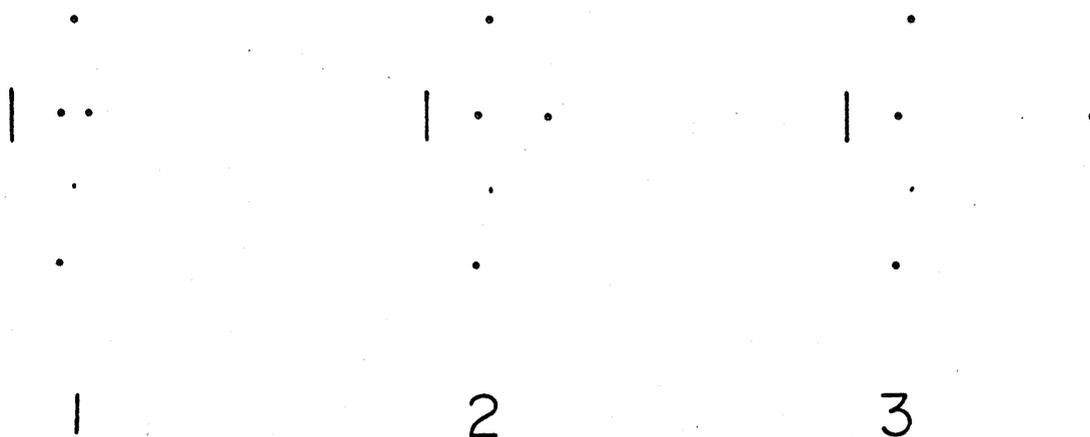


Figure 11. Spatial relationship between the inspection line and test figures 1, 2 and 3 (black dots) in Experiment VIII. The red dots are the fixation points.

illuminated throughout each testing session.

In this experiment only the displacement of the T-dot nearest the I-line was measured. The method of measuring the figural after-effect was the same as in the previous experiments (Chapter III). That is, a subject first made six practise alignments, three with the moveable dot offset from the left of the test dot nearest the I-line, and three from the right. The six control and six experimental alignments were obtained in the usual manner.

Only one of the three test figures was used in any one session. Eighteen subjects served in this experiment with six in each T-condition. The criterion of fixation on the red dot was the same as in the previous experiments. (Two students did not maintain constant fixation.)

### Results

The difference between each subject's mean control and mean experimental alignments was regarded as the magnitude of displacement. The results are shown in Table IX where a negative value indicates displacement toward the I-contour; no sign indicates displacement away from the I-line. Duncan's Range Test showed that all the groups were significantly different from one another ( $p < .01$ ). Individual  $t$  tests (see Table IX) between the control and experimental settings in each condition showed that there was significant displacement toward the I-line in Condition 1, and displacement

Table IX

The Magnitude of Displacement of the Left T-dot for Each Subject in Experiment VIII. Negative Values Indicate Displacement Toward the Inspection Figure; No Sign Indicates Displacement Away from the I-line.

Test figures			
	1	2	3
	-148	87	30
	-289	- 98	129
	-220	-109	87
	-136	- 72	173
	- 89	- 44	39
	-219	- 14	125
Mean:	-184	- 42	97
S <sup>2</sup> :	5,234	5,191	3,107
t	6.220*	1.418	4.263*

\* $p < .01$

away from the inspection figure in Condition 3. The control and experimental alignments were not significantly different in Condition 2.

### Discussion

The prediction which stated that the distance between two test points (or size) of the test figure can affect its displacement was upheld by the results of this experiment. Test Conditions 1 and 2 showed that the magnitude of displacement decreased as the distance between the T-dots was increased. With a further increase in distance between the test dots the direction of the figural after-effect changed from displacement toward the I-line when the dots were separated by one-eighth inch, to displacement away from the inspection figure when the dots were one inch apart.

These results therefore show, as the above interpretation of the satiation theory has suggested (Chapter IV, Section 4.2), that a test figure may be displaced either away from or toward an inspection figure. The direction of displacement will depend upon a number of variables (see Chapter IV, Section 4.2, p. 77) such as the size of the T-figure in this experiment.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This investigation has raised a number of difficulties for Deutsch's theory. It has shown that as two test points are moved from an inspection figure, the phenomenal distance between them increases. According to Deutsch's model the apparent distance between two points must be greatest at and immediately around an inspection figure and decrease with increasing separation of the I- and T-figures.

It was also shown that when the length of an inspection line passing through two test points was varied, the phenomenal distance between these points was changed. This seems to suggest a field effect which Deutsch's model has not considered. Phenomenal distance in Deutsch's theory depends only upon the level of excitability between two points. Further investigation of the level of excitability between two points in relation to the level beyond these points seems indicated.

This study and earlier investigations have shown that contrary to the prediction from Koehler's satiation model a test object may be displaced toward an inspection figure. It was also found that phenomenal distance between two points in a homogeneously satiated region may be greater than in an unsatiated area. Again, this appears to be contrary to the satiation theory. It was suggested, however, that these results could be explained within the framework of Koehler's model.

Briefly, the satiation theory states that when two points are exposed in the visual field, satiation will initially increase the phenomenal distance between them. With continued inspection the pattern of satiation will change so that the points will begin to move toward each other. The crucial question is the period of time over which this growth and subsequent reduction in apparent distance takes place. It was suggested that, the rate of this growth and shrinkage must depend upon such variables as the level of satiation in which a figure is placed, the lengths of the inspection and test times, the shapes, brightness and sizes of both figures, as well as their spatial separation. It was argued that it would thus be possible to show test figure displacement either toward or away from an inspection figure, depending upon the relative contributions of these variables. This was tested and confirmed by varying the distance between two test points.

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