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The Phenomenal Displacement of Lights as a Function of Various Background Stimuli

Raymond M. Daly

Loyola University Chicago

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THE PHENOMENAL DISPLACEMENT OF LIGHTS AS A FUNCTION OF VARIOUS BACKGROUND STIMULI

by
Raymond M. Daly

A Thesis Submitted to the Faculty of the Graduate School of Loyola University in Partial Fulfillment of the Requirements for the Degree of Master of Arts

June
1963
ACKNOWLEDGMENTS

The author is especially indebted and grateful to Dr. Paul von Ebers for his help and encouragement throughout the different phases of this experiment. I am also indebted to him for the use of the experimental equipment which he so kindly volunteered.

The author expresses his appreciation to Dr. Edmund P. Marx for his advice and guidance during the development of the problem.

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CHAPTER I
INTRODUCTION

It has been evident for centuries that what one perceives is not always in perfect correspondence with the situation as it objectively exists. Perception of this type is called a "false" perception or more correctly an illusion. Illusions are considered "normal" and have been used by psychologists as a means of finding clues to the understanding of the process of perception.

One of the most famous illusions studies is that of apparent motion. An example of this would be a succession of lights, flashing one after another at a suitable rate, which give an illusion that movement occurs. This illusion is technically known as the phi-phenomenon. This phenomenon is closely related to a problem that is central to the study of perception in general. This problem is concerned with how the organism integrates discrete impressions it receives from the environment. Any adequate theory of perception must attempt to answer this question, thereby, integrating this phenomenon with its principles.

The phi-phenomenon is most often studied experimentally by using an apparatus which allows the presentation of two or more lights, one after the other. Most of this research has been centered around the discovery of the factors which must be
present in order to get the illusion. Some of these factors are the following:

1) The lights must be presented at an appropriate brightness.
2) The lights must be of a certain size.
3) The lights must be a certain distance apart.
4) The lights must be presented at certain temporal intervals.

It has also been found by Brown and Voth (1937) and von Ebers (1960) that there are forces of attraction in the perceptual field when one views the phi-phenomenon. These forces cause a distortion in the perceived size of patterns of light in apparent motion except those which were directly connected with the lighting situation itself. That is they did not permit any background stimuli to influence the perception of the phenomenon.

It is the purpose of this study to investigate the empirical relationship between the perception of the size of a panel of lights in apparent motion and certain background stimuli. Specifically, what is being investigated is the judgment of the size of the phi-pattern as a function of various circles of paper included within this pattern and surrounding this pattern. A secondary aim of this experiment is to quantify this relationship.
In a critical review of the literature on apparent movement, Neff (1936) indicated that the first experimenter to discover in the problem of seen movement implications of importance for general psychological theory was Sigmund Exner in 1875. Exner explained this perceptual phenomenon in terms of the Helmholtian tradition with its identification of perception with inference.

Wertheimer (1912) wrote a classical article and explained the perception of apparent motion from the Gestalt point of view. In this article he treated the perception of motion in terms of a simple, unanalyzable experience. His method of experimentation set the pattern for most of the later work in this field. This experiment is in this very tradition. The method consists simply of the presentation of stationary stimuli, allowed to appear simultaneously, overlapping in time or succession. The possible variables in this situation comprise an immense number.

In later Gestalt theorizing Koffka (1935) suggested that lights seen in apparent movement become fused because of some force of attraction between them. He further states that the reality of this force is demonstrated by the fact that two stroboscopically presented lines appear closer together than two permanently presented lines. Maximum contraction of this apparent distance occurs, according to Koffka, when the rate of alternation
of the lights is optimal for phi or apparent motion. Brown and Voth (1937 reasoned that during optimal phi the resolution and cohesive, should result in the path of apparent movement becoming smaller and circular. Brown and Voth were able to produce substantially the effect predicted. Using an apparatus which permitted control of the distance separating the lights, time interval between lights, aperture and intensity of lights, they were able to measure this cohesive tendency at different time intervals, for different subjects and for different sized patterns.

In 1960 von Ebers performed an experiment modeled after that of Brown and Voth. In this experiment he attempted to add a dimension of similarity-dissimilarity by introducing different color conditions into the four light phi patterns. One of the central hypotheses was that the light conditions produced their maximal cohesion at time intervals producing the best phi. This was a verification of the Brown and Voth theory under new conditions.

Numerous theories have been put forward to explain apparent motion and other illusions. Fine reviews of these theories can be found in Boring (1942), Ladd and Woodworth (1911), and Woodworth and Schlosberg (1954). Woodworth (1954) suggested that more laboratory work is necessary in order to develop an adequate theory to explain these phenomena. One of the basic criticisms against most of the work done in this field is that the results
of experiments many times are not quantifiable. Greater quantification can do much to aid in the construction of a new theory since quantification discloses empirical relationships which theory must encompass. Zigler (1960).

A study by Obonai (1954) was concerned with induction effects and their influence on the perception of certain illusions. He concluded, "In the example cited we see that lines, circles, squares, triangles, etc., seem larger when they are adjacent to small-to-medium extents (the confluence effect) and smaller when they are adjacent to larger extents (contrast effect)" (1954, p. 59).

The Delboveuf illusion (concentric circles) which Obonai used were also used by Heuven (1941 a); (1942 b). He found that the inner circle appeared proportionately smaller as the corresponding outer circles became larger. He discovered that the size of the inner circle was always over-estimated except when the diameter of the outer circle became very large, at which point the effect of dissimulation outweighed the effect of assimilation, and the size of the inner circle was underestimated (1942 b).

Zigler (1960) used a variation of the Delboveuf illusion in which adjacent circles of various sizes were employed rather than concentric circles. This was chosen in preference to the Delboveuf illusion for two reasons. (1) A pretest with the Delboveuf illusion indicated that it did not create an illusion large enough to make possible varying amounts of the illusion. (2) The
Delvoue’s illusion does not allow for the investigation of an interesting setting of an illusion in which the center circle is adjacent to an extent of equal size.

Zigler tried to discover two things. (1) The percent of larger or smaller judgments as a function of the ratio of the size of the center circle to the adjacent circles. (2) The transition point at which the ratio of the size of adjacent circles to the size of the center circle is such that 50% of the judgments would be smaller and 50% larger. In general his findings agree with Heuven (1942 b). The data further indicated certain quantitative facts about the diameter of adjacent circles which could be used to indicate when contrast effects would overcome confluence effects or vice versa.

It is the purpose of this study to use the ideas cited above in order to measure the influence of various circles of white paper surrounding and included within a pattern of lights in apparent motion, on the perceived size of this pattern.
CHAPTER III

PROCEDURE

A. APPARATUS DESIGN

The basic description of the apparatus and part of the procedure is largely taken from von Ebers (1960) who used the same apparatus and a similar procedure in his study.

Four 12-volt, twenty-five watt automobile lamps are mounted inside separate light-tight boxes. The boxes measure one and five-eighths inches deep by three and one-quarter inches high by two and one-eighth inches wide. A photographic shutter and lens is mounted at the front of each box. Inside each box is a one inch by one and one-half inch piece of light-diffusing opal glass placed between the lamp and the front of each shutter. Mounted on the front of each shutter is a filter holder which contains a second piece of opal glass about one inch square, and in front of this, a slot or envelope into which can be placed any of several filters. The front of each filter holder contains a one-half inch aperture which can be masked down to one-quarter inch. Varying the diaphragm of the shutter permits variation of the brightness of the lights with even diffusion over the area of the aperture without distortion of the color quality of the light. The shutters are set at bulb and remain open for the duration of the experiment. Control of the duration of the lights is obtained by means of a timing mechanism which will be
described shortly.

Each lamp with its housing and shutter is mounted in a slot in a twenty-four inches by thirty-six inches piece of wood or masonite hardboard. Each slot is six inches long by one and one-half inches wide. The light housing is behind the masonite, the shutter being screwed into its housing from the front of the masonite through the slot. The lights in position are seen to form a square standing on one corner. The masonite panel is held about six inches from either end. The panel is placed on a table six feet from the viewing subject. (Appendix I).

The four slots into which the lamp housings are mounted are so cut in the hardboard that they form vertical and horizontal radii which are perpendicular to each other. When the lamps are placed at the inner extremes of their perspective slots the distance between the aperture centers of adjacent lamps measures exactly six inches. When the lamps are placed at the outer extremes of the slots this distance is exactly twelve inches. (Appendix I and Appendix II give respectively, the front view of the apparatus and a top view of the room.

The front surface of the panel is painted a flat black. Metal parts of shutters and lamp housings are masked by small squares of blackened cork-rubber sheeting, slotted to fit between the filter holder and the shutter. A screen of black transparent organdy material, about two and one-half feet square is mounted in front of the light panel to mask out the slots and other
details of the panel.

Each light is wired to two circuits, one of which goes to a common receptacle and thence to a variable transformer. This circuit is used when steady illumination of all lights is desired. The other circuit goes from each lamp through a mechanical timer to the same variable transformer. The circuit is used to produce various rates of alternation of lights by means of the timer, for the apparent movement portion of the experiment. Only one of these circuits is in use at a time. Polarization of all lines going to each light prevents shorting through feedback into the unused circuit.

The mechanical timer just referred to consists of two main elements: 1) a system of gears driven by a constant-speed motor, and 2) an industrial timer attached to the gear system by a pulley chain and consisting of four adjustable cams each of which activates a snap-action switch. The constant speed motor (Merkel & Korfve Gear Co., Chicago, 1 RSP) operates directly off of the 110 v. outlet. It is mounted in such a way as to drive a shaft containing six permanently fixed gears. These gears are mounted on a three-eighths inch shaft in a gear box whose dimensions are four and one-half inches by eight and three-eighths inches. The permanently mounted gears drive a second complementary set of gears which are not permanently fixed to their shafts. The six pairs of gears mounted on parallel shafts are partially immersed in an oil bath for constant lubrication
and quieting of their operation. Any one of the unfixed gears can be tightened, by means of a set screw, on its shaft so that its ratio to its driver gear will determine the rate of rotation of its shaft. When one of the unfixed gears is tightened to its shaft, the other unfixed gears simply ride on the shaft. A schematic drawing of the timer mechanism will be found in Appendix II.

The unfixed gear assembly is connected by means of a chain pulley to the shaft of a recycling cam timer (model J-1351, Industrial Timer Corporation, Newark, N.J.). The industrial timer consists of a metal chassis, three and one-half inches by four inches by six inches, to which are attached in parallel order four bakelite snap-action double-throw switches (10 amperes, A.C.). The switches are activated by adjustable cams mounted on a shaft, and driven by the constant speed motor plus its gear assembly. Activation of the switches in turn illuminates their corresponding lamps in the masonite panel. Thus, the cams can be set to activate their respective switches in any desired order for any desired portion of a cycle. For purposes of this experiment the cams were set to activate each switch for one-eighth of a cycle. Consequently, regardless of the speed of rotation of the timer shaft, each light was on for one-eighth cycle and the time interval separating consecutive lights was one-eighth cycle. The order of activation of the lamps was clockwise.
As was explained above, the use of different gear ratios provided for six different on-off time intervals of the lights in this instrument. Because of the physical limitations involved in the use of gears it was not possible to duplicate exactly the on-off time intervals used in the Brown and Voth Experiment.

The different time intervals provided by this apparatus are the following, in ms: 300, 250, 150, 90, 75, and 50. These represent the duration of each light and/or the temporal interval between lights. This range of on-off intervals is sufficient to produce experiences varying from succession, through phi to simultaneity. However, only one time interval of 90ms was used in this experiment.

To the left (from S's position) of the panel of lights described above was placed a similar panel with four lights, matching in all characteristics those of the first. However, the lamp housings with their shutters were so arranged by means of a system of pulleys that the positions of these could be simultaneously varied. The experimenter controlled this portion of the apparatus. By turning a knob behind the panel he could adjust the pattern of lights large or small, to suit the subject's perception of the size of the pattern on his right. The four lamps used in this part of the experiment were 25 watt, 12-volt auto lamps whose power source was a 19-volt Thordarson transformer. Shutters for these lights were set at bulb and
and remained open for the duration of the experiment. Identical
diffusing glass and filter holders with diaphragms were provided
for these lights so that they matched the right panel exactly.

The range of pattern size which S had available in this
left panel was from fourteen inches between adjacent lights
(maximum size) to four inches (minimum size). This range of
light separations accommodated adequately the range of phenomenal
perception for all S's for all experimental conditions.

Before describing the experimental room in detail the
quality of the filters used in the experiment should be briefly
described. The experiment called for one light condition. Under
this condition all the lights were white.

Since tungsten filaments ordinarily burn reddish-yellow it
was decided that some color correction should be used to
counteract this. The object was to produce a phenomenal white
with no apparent trace of color. An eastman Kodak Wratten filter
was selected because it was designed to correct the color tem-
perature of tungsten filament to a higher color temperature.
Color temperature readings indicated that that the unfiltered
light of the lamps used was approximately $2300^\circ K$. The phenomenal
appearance of the filtered light was a neutral white after a
number seventy-eight Wratten filter corrected the color tem-
perature of $2300^\circ K$ to $5500^\circ K$. Most subjects noticed no trace
of color.

Four circles of white paper were used as background material
in this experiment. Each circle was one-half inch thick and
was cut from sheets of white poster board paper. The outside
diameters of the circles are five inches, eight inches, eleven
inches, and twelve inches. Each individual circle of paper
could be attached to the transparent cloth masking screen in
front of the standard (phi) panel by using straight pins. The
outer rim of the five inch circle was inside and surrounded
by the phi pattern.

Since the distance between the lights of the phi pattern
was nine inches, the outer rim of the five inch circle was four
inches inside the phi light pattern. The outer rim of the
eight inch circle was also enclosed within the phi pattern and
its outer rim was one inch inside the light pattern. The eleven
inch circle enclosed the nine inch phi light pattern and its
inner rim was one inch outside the lights. The twelve inch
circle also surrounded the phi pattern and its inner rim was
two inches outside of the light pattern.

The experimental room was a laboratory booth seven feet,
nine inches by seven feet, ten inches. There were no windows
and the room was ventilated by a blower system with intake and
exhaust vents. The walls of the room were covered with black
buff paper from about two inches above the floor to about seven
feet. Parts of the ceiling were also covered to minimize ref-
lections. An overhead fluorescent fixture containing two 40-
watt lamps was masked off partially so that it provided only
indirect lighting to the room. A low level of illumination fell on both parts of the apparatus. Both sides appeared to be about equally dark to S.

The object of reducing the light in the room was to provide a fairly uniform dark field for the lights. This was thought to be desirable so that differentiation within the visual field would be reduced so as to interfere as little as possible with the operation of cohesive forces in the apparent movement undesirable to use a totally darkened room since changing levels of sensitivity and adaptation could be expected from trial to trial, and these might distort the experimental results.

Behind the apparatus the E sat on a camp stool almost completely invisible to S. Small partially masked apparatus lamp were used to illuminate the various parts of the mechanism (timer, variable transformer, switches) and the data sheets upon which C's adjustments of the variable stimulus lights were recorded. These small lamps were invisible to S from the front of the apparatus and cast an indiscernable amount of light on the rear wall.

S was seated in a chair six feet in front of the apparatus. The back of his head rested against an adjustable head rest to maintain the six-foot distance. At this distance the nine inch pattern of lights subtended a visual angle of approximately $20^\circ35'$.
B. THE EXPERIMENTAL DESIGN

The experiment proper consisted of six conditions to be presented in such a way that the effects of each could be measured. For all conditions there was one light condition. That is all the lights were the same color, namely, white. For all conditions there was one time interval of 90ms. The distance between the lights in apparent motion was nine inches for all conditions. The aperture size was one-quarter inch. Each subject was tested under only one condition.

One experimental condition that was not balanced was the relative position of the standard (phi) and variable patterns of lights. If there is any influence of this variable on the apparent size of the standard it may be assumed to have affected all experimental conditions in approximately the same way.

The six experimental conditions are as follows:

1) Under condition one, S had to match the pattern of stationary lights on his left with a pattern of stationary lights on his right.

2) Under condition two, S had to match the pattern of stationary lights on his left with a nine inch pattern of lights on his right in apparent motion.

3) Under condition three, S had to match the pattern of stationary lights on his left with a nine inch pattern of lights on his right in apparent motion. Under this condition the circle
with the five inch diameter was included within the pattern of the phi lights. The outer rim of the circle was four inches of the pattern.

4) Under condition four, S had to match the pattern of stationary lights on his left with a nine inch pattern of lights on his right in apparent motion. Under this condition the circle with the eight inch outside diameter was included within the pattern of the phi lights. The outer rim of this circle was one inch inside of the pattern.

5) Under condition five, S had to match the pattern of stationary lights on his left with a nine inch pattern of lights on his right in apparent motion. Under this condition the pattern of lights in apparent motion was surrounded by a paper circle with an eleven inch outside diameter. The inner rim of this circle was one inch outside the pattern of lights.

6) Under condition six, S had to match the pattern of stationary lights on his left with a nine inch pattern of lights on his right which were in apparent motion. Under this condition the pattern of lights in apparent motion was surrounded by a paper circle with a twelve inch outside diameter. The inner rim of this circle was two inches outside the pattern of lights.

C. SUBJECTS

Sixty subjects were used in the experiment. Forty-eight of these subjects were undergraduate students in a course in
Introducory Psychology at Loyola University, Chicago. Their median age was approximately nineteen years and the age range of the group was about four years. The other twelve subjects were graduate students in the psychology department at Loyola. No record was taken was taken of the age range or median age of this group. None of the subjects had any notion or ideas about the purpose of this experiment. All subjects had twenty-twenty vision, either corrected or uncorrected.

D. PROCEDURE

Each subject was scheduled to be tested under only one condition. There were ten subjects tested under each condition and a total of sixty subjects tested under all six conditions. The subjects were randomly assigned to the various conditions by E and since no subject was tested under more than one condition, no counterbalancing was necessary.

An experimental session for each subject consisted of twenty-three trials. The first three of these trials were practice trials and their results are not found in the final tabulations of the experiment.

When S entered the experimental room he was given five to ten minutes to become adapted to the semi-darkened room. During the period E gave instructions to each S as follows:
During the experiment you are to keep your head against the head rest at all times. You will notice that size of the pattern of lights on your left can be changed by me when I turn a knob behind this panel. The lights can be made to become larger or smaller. Your job throughout the experiment will be to inform me when you think I have set the pattern of light on the left so that it matches the pattern of lights on the right. When you think they are matched give me a signal so that I may record your response. As soon as you give me this signal close your eyes and I will tell you when to open them for the next trial.

Sometimes the lights on the left panel will be larger than those on the right panel and sometimes they will be smaller. You will be able to change the size of the lights on the left in either direction by saying either smaller or larger. When you say this I will move the lights in the desired direction. You may have me adjust the lights as many times as you wish or in any direction until you are satisfied that the lights on the left panel match the lights on the right panel.

As you are making your settings try to keep your eyes fixated on the center of the pattern. Try to judge the pattern on the right as a whole. Do not look at the separations between two individual lights. You may look back and forth between the two panels as often as you like but try not to take too long to make a setting.

Be sure that you make a direct visual comparison of the pattern on the right with that on the left on every trial. Do not try to rely on recall of where you set the left-hand lights on previous trials. This will defeat the purpose of the experiment. Sometimes I will move the lights far off of your previous settings; sometimes I will change them only slightly. If the pattern is too small tell me to make it large enough to match the right-hand pattern. If it is too large, tell me to reduce it until it seems to be the right size. Are there any questions?

The procedure used was the same for each experimental condition for all S's. Twenty trials were given in an alternately ascending and descending order. E recorded radial distance of the variable lights from the center of the pattern.
He read this distance to the nearest sixteenth of an inch from rulers mounted parallel to the path of the light houses.
CHAPTER IV

RESULTS AND DISCUSSION

A. PRESENTATION OF THE DATA

The first results that will be discussed will be the overall effect which the various conditions had on the estimation of the size of phi pattern. This should be of importance because it is necessary for further consideration to know whether or not a cohesive tendency was present and whether it was effected by the presence of the background stimuli. This, as it was stated before, is the main problem with which this experiment is concerned. Secondly, the data will be examined from a statistical viewpoint. The statistical technique known as the analysis of variance will be used to test the significance of the differences between the means of the conditions. If they are significant at a chosen level of confidence, we can reject the null hypothesis that $m_1 = m_2 = m_3$, etc. If this occurs we then have estimated statistically the effect of the various conditions of the perception of the size of the phi pattern.

With regard to the overall influence of the various conditions on the estimate of the size of the phi pattern, the data presented in Table 1 shows clearly that different perceptions were associated with various conditions. The mean that varies the most from objective equality of 4.5 is that of condition 2,
the pure phi condition. This evidence upholds one of the main assumptions of the experiment which was that there would be some underestimation of the size of the phi pattern which could be due to the operation of cohesive forces. It is also evident that all of the estimates were not in the negative direction. And at this point it seems that these effects could be due to the background of circles in these conditions. From Table I we can see also that the greatest amount of variance was under condition three with the five-inch circle. The least amount of variance was found under condition I with no with no movement. It seems logical that there should be little variance under condition 1 but there is no logical explanation of the amount of variance found under condition 5.

Figure 1 represents the proportion of physical equality of the mean estimations under each condition. It is easily seen that condition 1 or no movement is very close to physical equality. It is .99% of the physical equality judgment of 4.5 inches. Even in this case the subjects do tend to underestimate even with no movement. The pure phi condition is .841 of physical equality which again indicates a considerable amount of cohesion in comparison with the no movement condition. It is also clearly evident that from conditions 2 through 6 there is a steady increase in the estimate of the size of the pattern. And on conditions 5 and 6 there is an over estimation of .114 of physical equality for condition 5 and .037 for
TABLE I

MEAN AND VARIANCE ESTIMATES OF COMPARISON PATTERN SETTINGS
AT NINE-INCH LIGHT SEPARATION AT 90ms TIME INTERVAL OVER
SIX CONDITIONS.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean Radial Estimation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) No movement</td>
<td>4.349</td>
<td>0.0615</td>
</tr>
<tr>
<td>2) Pure Phi</td>
<td>3.787</td>
<td>0.148</td>
</tr>
<tr>
<td>3) 5-Inch Circle</td>
<td>3.904</td>
<td>0.425</td>
</tr>
<tr>
<td>4) 8-Inch Circle</td>
<td>4.114</td>
<td>0.132</td>
</tr>
<tr>
<td>5) 11-Inch Circle</td>
<td>4.564</td>
<td>0.312</td>
</tr>
<tr>
<td>6) 12-Inch Circle</td>
<td>4.667</td>
<td>0.154</td>
</tr>
</tbody>
</table>
condition 6. The different subjects judged the size of the phi pattern to be larger than it actually was on these latter two conditions.
B. STATISTICAL INTERPRETATIONS

At this point an analysis of variance was performed on the experimental data which has been presented graphically thus far. The purpose of this statistical tool was to evaluate the relative influence of the six conditions on the perceived size of the pattern of lights. For those experimental conditions that proved to be significant by the F test further analysis by the t test was done to estimate which conditions contributed to the high F ratios.

The analysis of variance is presented in Table 2.
### Table II

Analysis of Variance for Perceptual Estimation of the Size of a Nine-Inch Pattern of Lights in Apparent Motion by Sixty Subjects, One Light Condition and One Time Interval. There were 10 subjects.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Variance Estimate</th>
<th>F</th>
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<td>Rows (Individuals)</td>
<td>147.75945</td>
<td>9</td>
<td>1.6400</td>
<td>7.826</td>
</tr>
<tr>
<td>Columns (Conditions)</td>
<td>125.46809</td>
<td>5</td>
<td>25.0936</td>
<td>13.305+</td>
</tr>
<tr>
<td>Interaction</td>
<td>84.998</td>
<td>45</td>
<td>1.8860</td>
<td>14.609+</td>
</tr>
<tr>
<td>Within Cells</td>
<td>147.175</td>
<td>1140</td>
<td>0.1291</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>372.390</td>
<td>1199</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ p < .01
It can be seen in Table 2 that the different conditions produced significant changes in apparent size of the phi pattern. This is shown by the F value of 13.305 for the columns or conditions which is far beyond the .01 level of significance. This means that as the conditions changed, the subjects' perception of the size of the pattern also changed and that the change could have occurred less than one time out of a hundred by chance.

**TABLE III**

**T VALUES AND SIGNIFICANCE LEVELS FOR THE DIFFERENCE BETWEEN EVERY CONDITION COMPARED WITH EVERY OTHER**

<table>
<thead>
<tr>
<th>Means</th>
<th>Mean Difference From Equality</th>
<th>T Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) No Movement</td>
<td>- .151</td>
<td>( \bar{x}_6 ) ( \bar{x}_5 ) ( \bar{x}_4 ) ( \bar{x}_3 ) ( \bar{x}_2 ) ( \bar{x}_1 )</td>
</tr>
<tr>
<td>2) Pure Phi</td>
<td>- .713</td>
<td>( \bar{x}_5 ) NS</td>
</tr>
<tr>
<td>3) 5-Inch Circle</td>
<td>- .596</td>
<td>( \bar{x}_4 ) .001 .001</td>
</tr>
<tr>
<td>4) 9-Inch Circle</td>
<td>- .360</td>
<td>( \bar{x}_3 ) .001 .001 .05</td>
</tr>
<tr>
<td>5) 11-Inch Circle</td>
<td>+ .064</td>
<td>( \bar{x}_2 ) .001 .001 .01 NS</td>
</tr>
<tr>
<td>6) 12-Inch Circle</td>
<td>+ .167</td>
<td>( \bar{x}_1 ) .01 NS NS .001</td>
</tr>
</tbody>
</table>

**Significance Levels**
It can be noted in Table 3 that condition 1 with no movement differs significantly from condition 2 or pure phi. The cohesive tendencies were strong enough in condition 1 to bring about this statistical significance. Condition 1 was also significantly different from condition 3 with the five-inch circle. Since the five-inch circle was close to the size of the phi condition this is understandable. Condition 1 does not differ from conditions 4 and 5 which include the eight-inch circle and the eleven-inch circle respectively. It will be remembered that the outer rim of the eight-inch circle was one inch inside the lights and the inner rim of the eleven-inch circle was one inch outside the lights. Thus the mean estimation of the estimates for conditions 4 and 5 were 4.140 inches and 4.564 inches which were very close to the mean of condition 1 which was 4.349. This is to be expected because if the subjects use the circles in some way to make their estimations and the circles are placed very near to physical equality, then there should be no significant difference between judgments made with no movement which is very near physical equality and conditions 4 and 5. Condition 1 is significantly different from condition 6 with the 12 inch circle. This means that the subjects tended to overestimate the size of the pattern to such a degree that it was significantly different from an estimation with no movement.
Condition 2, or pure phi, was significantly different from conditions 1, 2, 4, 5, and 6. It was not significantly different from condition 3 with the five-inch circle. The mean of the judgments for condition 2 was 3.787 inches and for condition 3 were not so affected by the presence of the five inch circle so as to make them significantly different from the pure phi condition.

Condition 3 was significantly different beyond the .01 level from conditions 1, 5, and 6 but was not significantly different from 2 or 4. The mean in condition 3 was 3.904 and 4.140 respectively.

Condition 4 was significantly different from conditions 2, 5, and 6. Thus it did not differ significantly from condition 7 with no movement, or condition 3 with the five-inch circle.

Condition 5 with the eleven-inch circle was significantly different from all of the other conditions except condition 6 and condition 1. Thus it is not significantly different from condition 6 with a circle one-inch greater than its outer rim and from condition 1 with lights without movement which are one inch inside the inner rim of the eleven-inch circle.

Condition 6 differed significantly from all conditions except condition 5. This is to be expected because the size of the circles used in these conditions differed by only one inch. And it does not seem that a difference of one inch between
circles is enough to bring about a significant difference in the perception of the light patterns enclosed with the circle.
C. DISCUSSION

From the results it is evident that there was a difference in the perception of the size of the phi pattern from condition to condition. In general it can be seen that there was considerable underestimation of the size of the pattern in condition 2 or the pure phi condition. In this respect the results of the present experiment were very similar to those found by von Ebers (1960). There was a greater amount of underestimation in this experiment than in von Ebers' but this could be due to the fact that a different sized phi pattern was used in this experiment. A six and a twelve inch pattern was used by von Ebers while this experimenter used a nine-inch pattern. Nevertheless there were cohesive tendencies found in this condition and this could possibly be attributed to the interaction of the cohesive and restraining forces as von Ebers (1960) suggests.

When the various circles of paper are introduced between and around the lights there is a change in the subjects' perceptions of the pattern. In general, it seems that the subjects used the outer rim of the circles included within the light as their frame of reference for judging the size of the pattern. As the size of the circles increased the estimations of the subjects increased. The estimations increased so much that a point was reached when the estimations were greater than physical equality. This occurred when the lights
were surrounded by the circles. A tentative explanation of this phenomenon might be that since the circle of paper gives the person some frame of reference he uses it to make his judgment. It is much easier to make a judgment using a stable frame of reference such as a circle than to rely on a pattern of moving lights. This effect can not be explained simply by saying that it is due to confluence or contrast effects. The confluence effect which states that objects seem larger when they are adjacent to small extents, can not be adjacent to small extents used because as the size of the paper circles increased, the subjects' estimations increased. Nor can the effects be fully explained by the contrast effect which states that objects seem smaller when they are adjacent to larger extents. Again the pattern was judged as being small when there was a small circle present. It was noticed by E that when he viewed the lights in apparent motion surrounded by a circle or enclosing the circle, the circles seemed to attract the light pattern. The pattern never seemed to cross the border of the circle but ones perception of the pattern was definitely disturbed by the presence of the circle. Thus there has to be more extensive work done on this nature in order to explain this phenomenon. Any attempt of this author to give a satisfactory explanation at this point would be too tentative to be useful.
CHAPTER V

SUMMARY

The purpose of this study was to investigate the empirical relationship, between the judgment of the size of a pattern of lights in apparent motion as a function of various circles of paper included within and surrounding this pattern. The present experiment was modeled after those of Brown and Voth (1937) and von Ebers (1960) who found that the path of apparent movement becomes smaller and circular during optimal phi.

The results of this experiment showed that there was a definite effect on the subjects' estimation of the size of the pattern due to the presence of these circles. A statistical analysis was performed and a tentative explanation was given in order to explain the results.
BIBLIOGRAPHY

The thesis submitted by Raymond M. Daly has been read and approved by three members of the Department of Psychology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Arts.

May 20, 1962

Date

Signature of Adviser