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M. E. Wingett
Grinnell College

C. F. Haner
Grinnell College

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M. E. WINGETT AND C. F. HANER

I. INTRODUCTION

The first serious attempt at control and analysis of apparent movement was made by Exner in 1875. At first he believed it to be the result of 'diffusion circles' emanating from each of the retinal points stimulated, but when the phenomenon was elicited by stimulating a point in each retina he advanced as his explanation a tendency of the observer to see motion whenever the stimuli received made such an appearance possible.

Stratton, in 1902 and 1911, reported on his investigations and gave an explanation in terms of a conscious organization of sensations. He spoke of a 'relational activity of the mind' which interprets the incoming sensations and gives to them the meaning of movement.

Max Wertheimer (1912) explained it in physiological terms; stimuli at various points in visual space are correlated with dsturbances in corresponding regions of the visual cortex. There occurs in the visual cortex a sort of 'short circuit' and corresponding to this 'short circuit' is the perception of illusory movement between the external stimuli. To him apparent movement was a new 'elementary mental experience' and to avoid the incumbences attached to the concept of sensation he gave it a name of its own, the 'Phi-phenomenon'.

In 1920 F. L. Dimmick described it as a 'psychological correlate' of the perception of movement, this 'psychological correlate' being a 'gray flash', a reflection in consciousness of a stimulus complex necessary for the visual perception of movement.

G. D. Higginson in 1926 explained the phenomenon as due to multiple factors. He described it as a form of abstractive perception determined by stimuli, receptors, and central organs, and dependent upon experiential items.

The possibility of eye movements being a significant part of the phenomenon was obviated in 1929 by Guilford and Helson. They made motion pictures of eye movements simultaneously with the occurrence of apparent movement and found no correlation. They concluded that if anything, eye movements would interfere with the perception of good phenomenal movement.

II. STATEMENT OF THE PRESENT PROBLEM

It is the purpose of this paper to present the Phi-phenomenon as an interpolation based on previous learning, that the conditions under which apparent movement occurs are similar to previous conditions in which real movement was perceived, and that whether or not apparent movement is perceived is dependent upon the "possibility" of it occuring as determined by previous experience.

III. EXPERIMENTAL METHOD

(A) Subjects: Nineteen subjects were tested. All were male college freshmen. The only requisites were:

1. normal vision in both eyes.
2. no knowledge of the Phi-phenomenon.
3. no physical abnormalities of the face, especially in the eye region.

(B) Apparatus: The apparatus (Figs. I & II) consisted of a rectangular box in which were two electric lights, an electric motor and a disk with a circular hole near its periphery. The motor was situated in the center of the box, its shaft projecting forward. The electric lights (B) were situated near the front and equidistant from the shaft of the motor that projected between them. The distance between the centers of the bulbs was the interocular distance. The disk (R) was securely mounted on the shaft in front of the light bulbs in such a way that the hole cut in it would alternately expose each of the light bulbs as it rotated. Directly in front of the disk was a plywood partition (Y) having a circular hole on each side corresponding to the positions of the lights. Placed in front of this partition was a sheet of milk-glass (X) that covered both holes in the partition.

Both lights were on continuously but they were hooded to emit light only to the fore, the hoods extended to just-clearance distance from the rotating disk. The result was that rotation of the disk caused alternate illumination of the milk-glass covered holes. These alternately illuminated areas were the basis of the stimuli which were figures cut in a black cardboard sheet (S) that was placed in front of the milk-glass such that each stimulus figure was directly

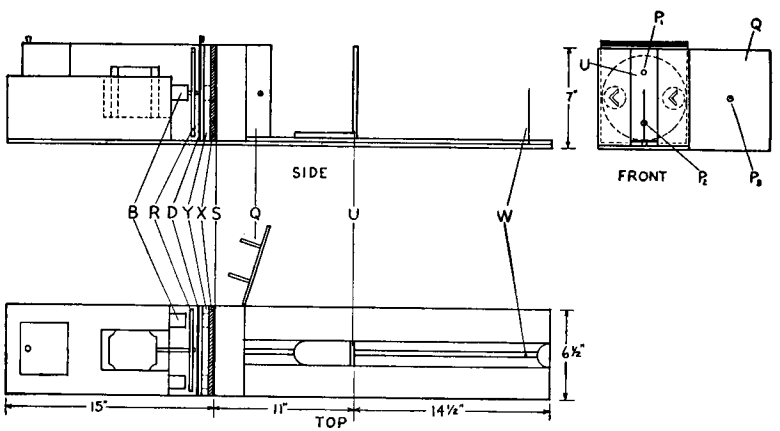

Fig. 1. Apparatus with top and left side removed.

B—light bulbs (inside hoods)
R—rotating disk
D—drop
Y—plywood partition
X—milk glass
S—black cardboard sheet
Q—upright "Q"
U—upright "U"
W—wire upright
P_1,P_2,P_3—fixation points

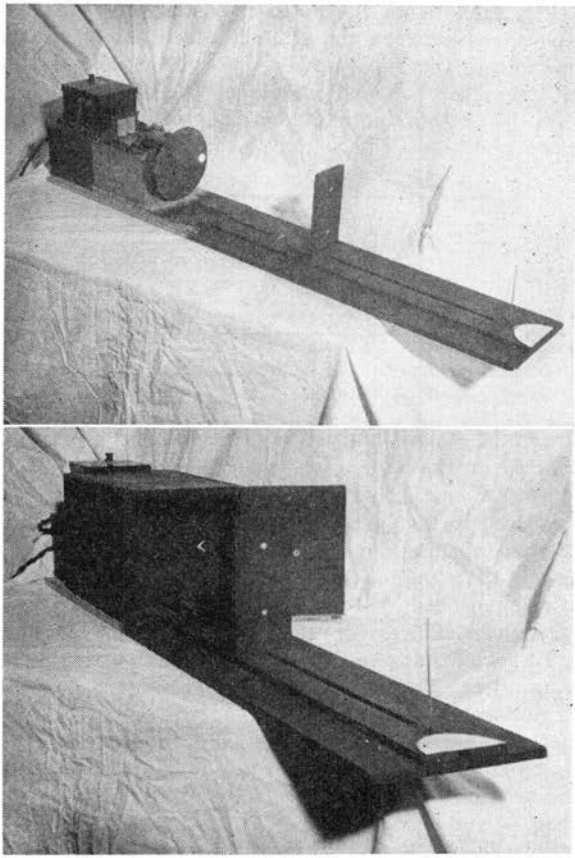

Fig. 2. Apparatus: above; box removed to expose roing disk, hole directly in front of right light. Below: appartus ready for use, disk in same position as above.

in front of an illuminable area. The figures used were two arrowheads pointing to the left, these figures constituted the object pattern. Commencement and cessation of stimulation was accomplished by means of a drop (D) situated between the plywood partition and the rotating disk.

Projecting forward from the front of the box for a distance of 25½ inches was a platform along the middle of which were two uprights. One, a wire (W), was near the observer's end of the platform and was used as a reference point by the subjects. The other, a wooden upright (U) 2⅝ inches wide and the height of the box (7 inches), was situated 11 inches from the front of the box. This upright separated the stimulus field such that the right stimulus was visible only to the right eye and the left stimulus visible only to the

left eye. (Fig. III). From the position of the observer this upright filled in the space between the stimuli. Placed along a mid-vertical line on the front of this upright were two yellow dots (P1 & P2), P1 equidistant from the top and middle of the upright and P2 equidistant from the bottom and middle of the upright. These yellow dots were fixation points.

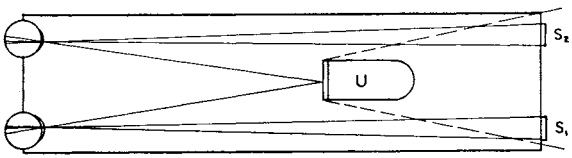

Fig. 3. How upright U separates the stimulus field. (S_1 & S_2-stimuli).

A third upright (Q) with a yellow fixation point (P3) in its center could be placed on the outside and at either side of the front of the box and turned to make a right angle with the line of vision. This upright was used to test peripheral vision of the Phi-phenomenon.

All visible parts of the apparatus were a dull black except the fixation points and the stimulus figures. All uprights were removable and used only when needed.

(C) Experimental Procedure: The experiment was conducted in a dimly lit room, the source of this light was located at a distance behind the subject. Ten of the subjects were tested with the left arrowhead noticeably brighter than the right one; with the remaining nine both arrowheads were of the same intensity.

Before each subject was tested he was acquainted with the meaning of "fixate" and "seeing peripherally." He was then given these instructions:

> There will be three parts to this experiment. In each case I want you to report to me as accurately as possible what you see in the front of this box. There is no time limit and there is no "correct" answer. All you must do is report just what you see.

The three parts of the experiment were as follows:

Part A, Section 1. Subject in position with tip of nose against wire upright. Upright Q absent, upright U in position. Subject instructed to fixate on point P1. Stimulus exposed, subject's report.

Section 2. Same as above except that subject is instructed to fixate on point P2. Stimuli exposed, subject's report.

Section 3. Same as Section 1 except that subject is instructed to fixate on a point between P1 and P2. Stimuli exposed, subject's report.

Part B Upright U removed, upright Q in position on one side of the box at an angle of 30 degrees (Fig. I). Subject in position with head turned toward upright Q, one eye covered. Subject instructed to fixate on point P3. Stimuli exposed, subject's report.

Part C Subject in position with tip of nose against wire upright.

Uprights U and Q removed. Subject instructed to gaze straight ahead. Stimuli exposed, subject's report.

Parts A and B were varied in order of presentation to avoid possible erroneous results due to "knowing what to look for". Part C was always presented last. It was designed to determine whether or not the subject could see Phi in the "normal" situation in case he did not see it in Parts A and B, and also to check on whether what was seen in Parts A and B was the same thing as that seen in Part C.

The stimulus on the right (first stimulus or stimulus 1) was always exposed first.

IV. RESULTS

In sections 1 and 2 of Part A, and in Parts B and C all of the subjects saw the Phi-phenomenon. That is, when the stimuli were viewed peripherally and in the "normal" situation apparent movement was experienced. This occurred regardless of the difference in or equality of the intensities of the two stimuli.

However, in section 3 of Part A the Phi-phenomenon was not perceived. All that was seen was the alternate flashing of the two stimuli. The point between points P1 and P2 was on the same level as the two stimuli, and this point, the stimuli and the outline of upright U were all in the object pattern in this situation. The upright itself was supraliminally visible and perceived as situated between the observer and the vertical plane of the stimuli.

V. DISCUSSION OF RESULTS

In any of these situations in which Phi was perceived wherein the intensities of the stimuli were equal we would expect the direction of movement to be from the first stimulus to the second. This experience was reported by all subjects. However, according to Korte's Delta movement, when the intensity of the second stimulus is noticeably greater than that of the first movement will be from the second stimulus to the first. This did not occur, in all cases movement was reported as being from right to left. The explanation offered here is that the *form* of the stimuli was the significant determiner of the direction of motion. The stimuli in the form of arrowheads pointing to the left suggested movement in that direction, regardless of the difference in intensity. If this explanation of direction of movement in terms of suggestion is correct we are free to assume that a higher cortical function than that of the visual cortex has entered into the interpretation of movement.

The other item for discussion is provided by the results of section 3 of Part A. In sections 1 and 2 the upright U appeared homogenous with the black background of the vertical plane of the stimuli and thus appeared as a part of it. Under these conditions Phi was perceived. However, in section 3 upright U was perceivable as situated between the observer and the stimuli. Under these conditions Phi was destroyed. This again is evidence of the operation of a higher

cortical function; the subject, aware of the fact that an object intervened between him and the area where movement should occur, did not perceive movement. It is significant that Phi was seen in Part C wherein the conditions were the same as in section 3 of Part A except that upright U was absent. Further substantiation of the operation of a "rational element" is provided by the subjects' answer that they could "visualize" movement as still occurring *behind* upright U under the conditions obtaining in section 3 of Part A.

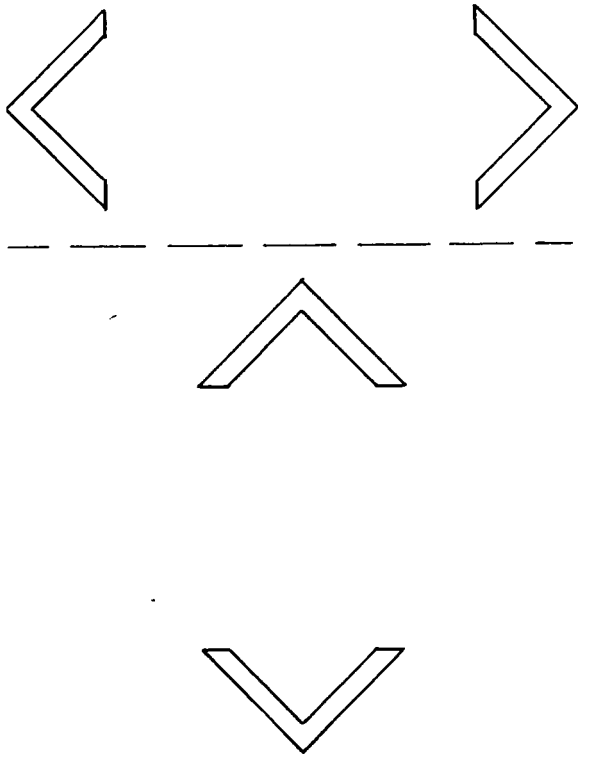

Figure 4

The implication from these two results is that higher mental processes are functional in the perception of the Phi-phenomenon. This is indirectly corroborated by Higginson's conclusions that more than the visual element enters into the perception of apparent movement.

Another finding which substantiates the entrance of a "rational element", "interpolation", into the interpretation of apparent movement is that of third dimensional Phi. If two stimuli are presented in the form arrowheads pointing in the opposite directions (Fig. IV) the movement experienced will be that of one stimulus turning about its basal axis out into space toward the observer and then on around into the position of the second stimulus. In terms of Wertheimer's 'elementary mental experience' or 'short circuit', or even Dimmick's

'gray flash', movement between these two stimuli would consist merely of the common linking experience. In this case the "logical" movement is provided by an integrating higher cortical function that interpolates movement between the two stimuli.

VI. SUMMARY AND CONCLUSIONS

Results of this experiment give evidence that the phenomenon of apparent movement is to be explained in terms of a molar functioning of the brain. This general idea is advanced by certain other experimenters and is especially supported by the results of Higginson's experiments. Furthermore, investigations into apparent movement in the related fields of tactile and auditory stimulation point in the same direction.

On the basis of what has been presented we conclude that the Phi-phenomenon is a net resultant of the integrative functions of the higher cortical processes that give an interpretation of the total stimulus situation which includes and is based upon previous learning.

DEPT. OF PSYCHOLOGY,
GRINNELL COLLEGE, GRINNELL, IOWA.

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