APPARENT MOVEMENT IN RELATION TO HOMONYMOUS AND HETERONYMOUS STIMULATION OF THE CEREBRAL HEMISPHERES [1]

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Introduction

Apparent visual movement arises when two discrete stimulus points, p_1 and p_2, are presented in temporal succession under conditions of optimum spatial and temporal separation. If p_1 is given first and p_2 second, the movement is from p_1 to p_2. The position of p_2 in space with respect to p_1 determines the direction of the movement from its point of origin, for, if the position of p_2 were rotated 90 degrees, the movement vector would suffer a similar rotation. Hence, the phenomenon of apparent movement constitutes one of the most compelling examples of gestalten, in that the direction of the movement cannot be established until the second of the two points, p_2, has been presented. Thus, the phenomenon in its entirety is dependent upon p_1 and p_2 and is modified by any suitable change in either or both: that is, the excitations created by p_1 and p_2 form a *system* and hence are interrelated.

In the present investigation, a preliminary attempt is made to study the degree of interrelationship between cerebral excitations as influenced by their locus in the cerebral mass. In particular, is the interrelation stronger if p_1 and p_2 give rise to excitations in the same cerebral hemisphere than if they cause excitations in disparate hemispheres? Let it be supposed that at time t_1 we present the two visual points $\bullet p_1$ $\bullet p_1'$ and at time t_2 we present the two visual points $\bullet p_2$ $\bullet p_2'$. These four points are so related one to another gemetrically as to form the four corners of a square: $\bullet p_2$ $\bullet p_1'$. It is clear that the

$$\begin{matrix} \bullet p_2 & \bullet p_1' \\ \bullet p_1 & \bullet p_2' \end{matrix}$$

spatial and temporal parameters involved in the presentation of these stimuli are such as to make equally probable (a) movement from p_1' to p_2' and from p_1 to p_2, and (b) movement from p_1 to p_2' and from p_1' to p_2. In the first case we should have reciprocal *vertical* movement; in the second case, reciprocal *horizontal* movement.

[1] Reported in part at the Philadelphia meeting of the American Psychological Association, 1946.

Let it be supposed that the visual fixation point is at the middle of the square constituted by the four points and that the dimensions of the square are such that points p_1' and p_2' fall on one side of the retinal midline, and points p_1 and p_2 fall on the other. Then the stimulation from the primed points will go to one cerebral hemisphere and that from the unprimed points will go to the other.[2] If now, in this situation, we obtain predominantly reciprocal *vertical* apparent movement, we are forced to conclude that the interrelation between the homonymous points is stronger than between the heteronymous points; if we obtain predominantly reciprocal *horizontal* apparent movement, our conclusion is reversed; finally, if no dominance of one over the other is indicated, we may conclude that the two types of interrelation have approximately equal strength.

As a check, we may envisage an experiment in which the visual fixation point is to one side of the square of four points. In this case all four points would be homonymous.

Apparatus and Method

The apparatus consisted of two rectangular tunnels 3.5 in. by 5 in. placed at right angles to each other in such wise as to form a short-stemmed T. One objective was placed at the far end of the cross-piece and the other objective at the far end of the stem. The *S*'s eye was at the near end of the cross-piece. At the point of juncture of the two tunnels, a half-mirror was so placed that light from the objective at the far end of the stem was reflected from the mirror, whereas light from the objective at the far end of the cross-piece was transmitted through the mirror, to the *S*'s eye. The distance of the two objectives from the observation point was identical: 12 in.

The objectives were in the nature of white cards three in. by three in.; each bore three black dots, 0.5 mm. in diameter, arranged along an imaginary diagonal line such that the two end dots formed the diagonal corners of a five mm. square. When the two cards were illuminated simultaneously, the *S* saw four dots arranged in the form of a square; in the center of the square the *S* saw a single dot which served as a fixation point.

Light was reflected from the surface of the cards, and was provided by 10-watt incandescent bulbs. Two such bulbs were used as a source of illumination for each card. The bulbs were enclosed in an especially constructed container which projected the light through an opening in the tunnel near the objective. The set-up was so arranged that only light reflected from the surface of the cards reached the *S*'s eye.[3] The cards were illuminated in an alternating manner by means of a circuit provided with two rotary switches, in such wise that the interval of darkness in the visual field equalled the interval of illumination; the value of this interval was about .10 sec. It was found that this interval gave the most palpable and satisfactory apparent movement.

The *S* viewed the objective monocularly through a circular opening about .75 cm. in diameter in the near end of the cross-piece of the tunnel. He was provided with a crude chin rest, and his eye was about one inch from the opening. He saw under conditions of illumination a circular field.

Each *S* was given a brief description of the stimulus cards and told that two pairs of diagonal dots would be alternately flashed on and off; that under these conditions it was usual for the *S* to see the dots move from one position to the other. The positions of the dots were illustrated

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[2] It is assumed that the fovea suffers bisection as does the periphery of the retina.

[3] Considerable effort was made to obtain commercial 'instantaneous' bulbs with very little lag in illumination and extinction. A three-watt gas bulb with large electrodes was procured which fulfilled these requirements and was used in the preliminary experiments. It was found, however, that these bulbs provided too little illumination. It was finally decided to use a 10-watt incandescent bulb for the purpose. Since the time values involved in the experiment were large, the lag in illumination and extinction was found to present no problem.

to him on paper, and the paths of possible horizontal and vertical motion indicated. It was pointed out also that possibly for him the movement might be neither horizontal nor vertical, but rotary or of some other form. It was found necessary to 'indoctrinate' the *Ss* in this manner, in order to establish a 'priority of observation.' When this was not done, it was found that the *Ss'* experiences were phenomenologically less structured and that it was much more difficult to obtain quantifiable data.

The *Ss* were instructed: (1) to keep the fixation point in the center of the field at all times; it was pointed out to them that any change in the position of the point from dead center indicated movements of the head which were not desirable; (2) while fixating the point in the center of the field at all times, to report any observations of movement of the other points under the following heads, (a) vertical movement and (b) non-vertical movement.[4]

The *S* was given a compact hand switch which actuated a cumulative electric clock. He was instructed that he was to press the switch when the movement was vertical and to release it when the observed movement was non-vertical. Each period of observation was two min. A five-min. period of practice in observation and manipulating the switch was given prior to the experiment proper, and five-min. rest intervals were provided between periods. All experimentation was carried out in a dark room. After each observation period, protocols were obtained; in particular, the *S* was questioned regarding what he saw during the times he reported non-vertical movement.

Experiment I

In this experiment, eight *Ss* were used; all had had extensive psychological training. A series of four observations were made, which will be referred to as A, B, C, and D. In A, the fixation point was in the center of the 'square'; in B, it was three mm. to the right; in C, it was three mm. below; and in D, it was four mm. diagonally below the lower right dot of the 'square.' These observations were not made in the same order by the *Ss*; rather, the sequences were 'randomized' for each *S* in order to eliminate any observational bias.

The results are shown in Table I, in terms of the amount of time during which vertical movement was seen and the amount during which nonvertical movement was seen. Examination of the protocols showed that probably 95 percent of the non-vertical movement reported by the *Ss* was in the nature of horizontal reciprocating motion.

A calculation was made of the reliability of the differences for each of the four series of observations on the basis of the differences between the vertical and the non-vertical scores for each *S*. The results are as follows:

For A: t = 4.12; reliable at the one percent level
For B: t = .685; not reliable at the five percent level
For C: t = 10.795; reliable at the one percent level
For D: t = .76; not reliable at the five percent level

From these results it is evident that vertical movement predominated over horizontal movement in A and C; that is to say, in

[4] The *Ss* were given a careful description as to what was meant by *vertical* and *non-vertical*. The former was described as movement of the points from ceiling to floor; the latter as any other kind of movement, such as horizontal (from one side of the room to the other), diagonal, circular, etc.

those observations where homonymous cerebral excitations were pitted against heteronymous cerebral excitations, the inter-relations between the former were definitely stronger. Series B and D served as controls in this experiment, in that in these two series all four dots presumably caused excitations in the same cerebral hemisphere.

TABLE I

Time in Sec. During Which Vertical (V) and Non-Vertical (N. V.) Movements were seen by Each *S* under Each Condition, Experiment I

	A		B		C		D	
	V	N. V.	V	N. V.	V	N. V.	V	N. V.
1	73	47	0	120	89	31	29	91
2	91	29	65	55	120	0	107	13
3	120	0	120	0	120	0	120	0
4	59	61	0	120	120	0	0	120
5	110	10	0	120	105	15	109	11
6	73	47	120	0	113	7	111	9
7	117	3	63	57	92	28	2	118
8	120	0	10	110	120	0	120	0
Mean	95.4	24.6	47.3	72.7	109.9	10.1	74.8	45.2

Table I is worthy of study by virtue of the fact that at least two *S*s, namely Nos. 3 and 6, reported predominance of vertical movement regardless of the position of the fixation point. Whether this is attributable to the possibility that they ignored directions and fixed the center of the 'square,' or rather represents a factor of systematic individual difference, it is impossible to say. There are in the table other notable individual differences of a cognate character.

At the end of the series of observations each *S* was asked once more to report under condition A. In this instance, however, the *S*, after having watched for some seconds in the normal manner, was asked to bend his head to one side some 90 degrees and repeat his observations. In all instances the *S*s reported an analogous rotation of the direction of apparent movement. If under the normal condition, the movement had been from ceiling to floor, it now became a movement from wall to wall; and *vice versa.*

Experiment II

All the essential conditions of the preceding experiment obtained here. For this experiment however, 14 new *S*s were used, all students in an undergraduate course in psychology.

The stimulus cards were changed in the following manner. Small colored discs, three m m. in diameter, were used instead of black dots. The distance between the stimulus points was increased, so that the four now formed a 'square' 10 mm. on the side. Red, green, yell ow, and blue colors were used; in Condition A, the upper left, upper right, lower left, and lower right dot were, respectively, Y, R, B, and G, while in Condition B they were G, R, G, and R. A smal black dot was still used as a fixation point, however, and at the same distance from the 'moving' points as in the corresponding conditions in the preceding experiment.

A change was made also in the fixation device, to make the task of visual fixation more tangible for the observer. A small black dot was placed on the half-mirror. The *S* was now instructed to keep this dot and the fixation point in alignment at all times, in such wise that but one black dot was visible in the visual field. Any slight movement of the head would produce two black points in the field, thus providing him with a cue for the necessary adjustment.

In this experiment observations were carried out only under conditions A and B.

Results are given in Table II. Examination of the protocols again shows that the non-vertical movement reported by the observers was predominantly horizontal in nature, although not to the same overwhelming degree as in Experiment I. Some reported circular movement, others movement along a diagonal. Still others reported occasionally a break-down of the movement pattern.

TABLE II

TIME IN SEC. DURING WHICH VERTICAL (V) AND NON-VERTICAL (N. V.) MOVEMENTS WERE SEEN BY EACH *S* IN CONDITIONS A AND B, EXPERIMENT II

	A		B	
	V	N. V.	V	N. V.
1	93	27	100	20
2	75	45	72	48
3	110	10	88	32
4	93	27	98	22
5	116	4	96	24
6	27	93	39	81
7	120	0	120	0
8	120	0	44	76
9	48	72	0	120
10	116	4	0	120
11	100	20	0	120
12	80	40	81	39
13	60	60	97	23
14	46	74	15	105
Mean	86	34	60.71	59.29

The results are recorded in seconds.
V = vertical movement; N.V. = non-vertical movement.

Calculation for condition A gives a $t = 3.15$ which is reliable at the one percent level. No attempt was made to calculate the reliability for condition B, since it is evident from inspection that the difference in time is negligible.

Inspection of Table II again reveals the fact that certain observers reported a great predominance of one kind of movement regardless of the condition under which the observations were made.

As in Experiment I, at the end of the series of observations, the *Ss* were asked to report once more under condition A, with the head inclined 90 degrees, after having watched the movement from a normal position for a short time. All *S*s except one reported a corresponding rotation of movement. This change in the direction of the motion uniformly impressed these psychologically naive *S*s, in particular by virtue of the fact that the discs were of different color, and the change was therefore the more spectacular. Thus, if in the immediately preceding normal position the *S* had seen vertical movement, this movement would be between the red and green discs, and the yellow and blue discs, respectively. Upon rotating the head, the movement took place between the red and yellow discs, and the blue and green discs, respectively.

In this experiment, as in the preceding one, when the *S* reported rotation of movement, he was asked to make a definite attempt to restore the movement to its original direction. All reported a remarkable stability of the movement and found themselves unable to change the direction at will.

The one *S* who formed the exception reported such frequent shifts of movement from vertical to non-vertical when in a normal position that the test could not be made for him.

Miscellaneous Observations

(a) In the course of these experiments it was noted that the rapidity of fluctuation between vertical and non-vertical movement varied considerably from *S* to *S*, although no attempt was made to measure this aspect of the phenomenon. The impression was gained, however, that under conditions when all four stimulus points involved homonymous cerebral excitations the frequency of shift was much greater than when homonymous excitations were pitted against heteronymous excitations.

(b) In Experiment II a number of *S*s complained spontaneously that they "couldn't tell just exactly when, for example, the red dot changed into the green dot, and *vice versa*."

(c) The writer spent, altogether, a number of hours acting as *S* in this experiment. At the beginning, for any given condition of observation, he experienced the shifts in the direction of movement reported by the other *S*s; as time went on, however, condition A gave uniformly vertical motion, without shift, and condition B gave similarly uniformly horizontal motion. Many times, while observing under A and seeing consistent vertical motion, the writer deliberately turned his fixation to the right of the field of the moving points, thus simulating condition B. Almost at once the movement would switch from vertical to horizontal. Upon restoring the line of regard, the motion would snap back into the vertical type.

(d) Another interesting fact reported by some *S*s (noted also by the writer) was that a given form of motion, e.g., the vertical, was often seen in two ways, *viz.*: (a) as a simple straight up-and-down reciprocal motion of the dots or, (b) as the vertical up-and-down motion of the end-points of an imaginary diagonal rod rotating back and forth on a pivot point at the center. This was observed particularly in condition A, where there was an actual dot in the center of the movement field.

Discussion

It was deemed unnecessary to perform a parallel experiment in which the *S*s were asked to report their observations in terms of 'horizontal' and 'non-horizontal' movement. While it may be conceded that the form of the instructions given might affect the *S*'s reports, this possible influence is irrelevant to the purpose of the experiment. The experiment was designed to determine whether any change in the direction of seen movement accompanies a change in the fixation point; in particular, to observe the nature of the seen movement (a) under conditions when homonymous stimulation only was present, and (b) when both homonymous and heteronymous stimulations were present. Any statistically reliable differences between the results given by these two conditions can be attributed only to the presumed change in cerebral excitation, and hence our finding that homonymous excitations are more closely interrelated than heteronymous ones cannot be impugned on these grounds.

Furthermore, the results obtained at the end of each experimental session, when the *S*s were asked to observe once more under condition A and then to bend the head to one side approximately 90 degrees, serve as a useful check. In all instances, the *S*s reported a corresponding rotation in the direction of the seen movement. In this connection, it is necessary to bear in mind that the definition of vertical movement given to the *S* was that of *movement from ceiling to floor*, and not as movement from forehead to chin.

Summary

Two pairs of visual stimulus points were presented to *S*s under conditions producing the phenomenon of apparent movement, but in such wise that two radically different forms of seen movement were available, *viz.*, vertical and horizontal.

By altering the position of the visual fixation point relative to the points in question, an attempt was made to determine whether homonymous cerebral excitations were more intimately interrelated than heteronymous cerebral excitations. In the event this were true,

one form of the movement should predominate over the other under certain defined conditions.

In the case where both homonymous and heteronymous forms of cerebral excitation were simultaneously present it was found that that form of the seen movement was predominant which had its base in the homonymous cerebral excitations. On the other hand, when only homonymous cerebral excitations were present, there was no clear predominance of one type of movement over the other.

It is concluded that two excitations existing in the same cerebral hemisphere are more strongly interrelated than two excitations existing in different cerebral hemispheres.

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