CORRESPONDENCE PROCESS IN MULTI-ELEMENT APPARENT MOVEMENT (3)
—INFLUENCE OF STIMULUS LUMINANCE—

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SUMMARY

The influence of stimulus luminance on the correspondence process in apparent movement was exmined. In each trial of the experiment, two patterns, each of which contained three dots of different luminance, were presented alternately. And the subject was required to describe the perceived motion of dots. The results revealed that although the luminance affected the emergence of apparent movement, it had little influence on the correspondence of stimulus elements itself, which was mainly determined by inter-element distance. The influence of luminance on the correspondence is secondary, compared with that of distance.

INTRODUCTION

The dot stimuli are frequently used in the apparent movement experiment. In the most simple case, one dot is presented as the first stimulus, and another as the second one. If they are presented under an appropriate spatiotemporal condition, the smooth movement of one dot is perceived.

When each stimuls pattern has several dots, some kinds of motion percept can be obtained from a pair of patterns. For example, when two patterns, each of which contains three dots aligned horizontally at regular intervals, are presented alternately in the manner that two leftmost dots of one pattern overlap two rightmost dots of the other, two kinds of motion percept can be seen, depending on the various stimulus conditions. Under some condition, the dots of the same position in each pattern are matched, and three dots are perceived to move back and forth together, which is named "Group movement". Under the other condition, two dots in one pattern are matched with those in the other that are presented at the same location and two remaining dots, that is, the leftmost one and the rightmost one are also matched. In this case two inner dots stand still and only one dot is seen to move from one end to another. It is called "Element movement" (Pantle & Picciano, 1976).

Also when the stimulus patterns contain many dots, the motion percept becomes ambiguous. For example, when a random-dot pattern is presented as the first stimulus and the same pattern which is displaced by certain distance to one direction is presented as the second stimulus, two kinds of motion percept are possible. If the displacement is very small, each dot in one pattern is

matched with the same dot in the other pattern, and all dots in the pattern are perceived to move together in one direction. But if the displacement goes beyond a certain extent, each dot in the first stimulus is matched with the nearest dot of the second stimulus, and the random movement is observed (Braddick, 1974).

In general, when each stimulus pattern contains more than one element, there exist several kinds of correspondence of element between patterns. So, several kinds of motion percept can be perceived from a pair of patterns, relying on the way of correspondence of elements. But usually, in each stimulus one or two kinds of motion percept are obtained. Here the question is what kind of correspondence is chosen from the possible ones in each stimulus and what factor determines it.

Many experiments on the correspondence process have been done using stimulus patterns of the same spatial configuration. But few studies dealt with the case in which the dots of each pattern formed different configuration. About the latter case Hirata (1984, 1985) examinated the relation between the inter-element distance and the correspondence of dots. He reported that the correspondence of dots depended much on the distance between them, and that the correspondence in which the sum of distances between matched elements is shorter is tended to be obtained out of the possible ones.

Besides the distance between stimulus elements, many stimulus factors are known to influence the appearance of the apparent movement and its quality. The luminance of stimulus is one of the basic factors of apparent movement (Korte, 1915; DeSilva, 1926, 1928). In this study, the influence of luminance of stimulus elements on the correspondence process was examined.

Although the earlier experiments were done with experienced subjects, most of the subjects in this study had no experience of apparent movement experiment. Sometimes the experimental results of experienced subject differ from those of naive subject. So, the experiment using stimulus elements of the same luminance was carried out as a control in Exp. 1, and then the variation of luminance was introduced in Exp. 2.

EXP. 1

METHOD

Subject: Five students of Sendai College and the author took part in this experiment and also in the following experiment as subjects. The author had enough experience of apparent movement experiment, and for the rest it was the first time to serve as subjects in the psychological experiment. Prior to the experiment, a general explanation of apparent movement was given to the native subjects. All of them had normal or corrected-to-normal vision.

Apparatus and Stimuli: A microcomputer (NEC, PC9801VX) was used for the preparation and the presentation of stimuli.

The apparent movement stimulus was a pair of three-dot patterns presented in the center of a CRT display of the computer. The dots appeared white against dark background. The luminance of dot and of background was 8.3 and 0.1 nit, respectively. Before the experiment, 50 pairs of three-dot patterns were prepared. Each pair of patterns was obtained by putting dots randomly in the cells of an imaginary 5×5 matrix, with the restriction that the overlap of dots might not occur

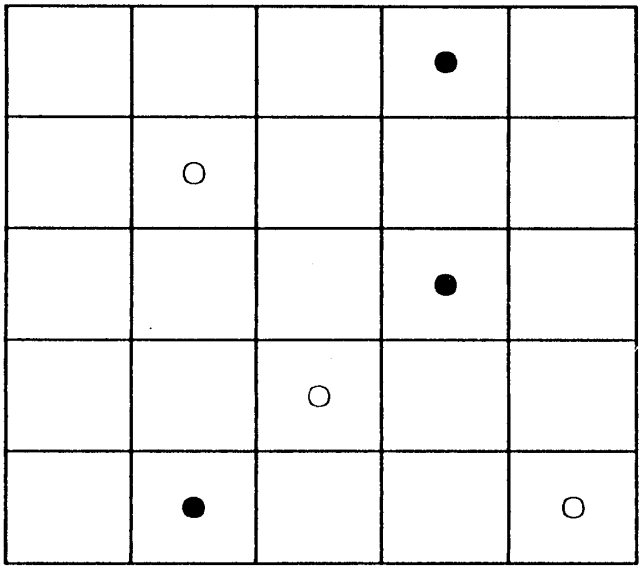

Fig. 1. An example of stimulus pattern. Open circles and filled circles were presented alternately. All of them appeared as white dots against black background. The matrix was invisible in the experiment.

between patterns. An example of stimulus patterns is shown in Fig. 1. The size of the matrix was 45 mm × 45 mm, and the diameter of the dot was 3 mm.

Procedure: The experiment was carried out in a dark room. In each trial two three-dot patterns of a pair were presented alternately in the center of the CRT display. The duration of each pattern was about 200 msec, and one pattern followed the other without time interval. The subjects observed the stimuli from the distance of about 150 cm. They were required to describe the perceived movement of dots. The restriction on the observation time was not imposed, and on the average, each trial took about 20 seconds. They were instructed not to gaze the particular dots during the observation. For each subject, 50 trials were given in random order.

RESULTS AND DISCUSSION

Same as in the earlier experiments, various kinds of correspondence obtained in this experiment were classified into three categories. First, in many trials three sets of one-to-one correspondence were obtained (ONE-TO-ONE), and three dots were seen to move back and forth. Secondly, in several trials two sets of one-to-two correspondence were obtained (ONE-TO-TWO). In this case "fusion" and "split motion" were seen at the same time. Thirdly in the other trials, while one-to-one or one-to-two correspondence was obtained, some dots remained unmatched with the others, which were seen only as blinking on and off (IMPERFECT). The examples of three kinds of correspondence are shown in Fig. 2.

ONE-TO-ONE was obtained more in the experienced subject than in the native subjects. But in the other aspects of the results, there was no difference between them.

Mean numbers and percentages of three kinds of correspondence obtained in the experiment are shown in Table 1. Among three kinds of correspondence, ONE-TO-ONE was obtained much

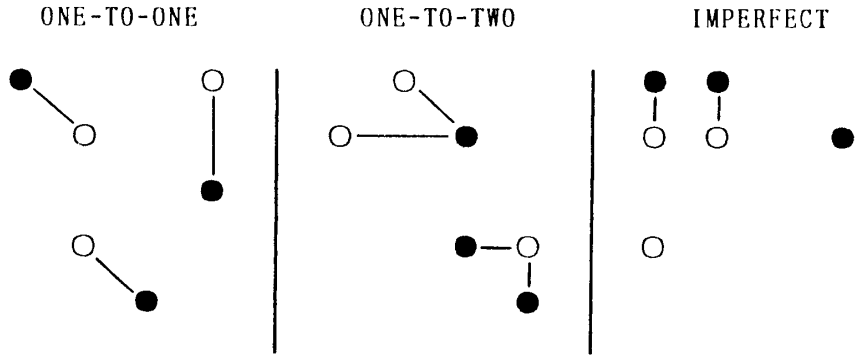

Fig. 2. The examples of three types of correspondence obtained in the experiment. The lines between dots represent the perceived motion.

Table 1. Mean numbers and percentages of three types of correspondence obtained in Exp. 1.

Type of correspondence	ONE-TO-ONE	ONE-TO-TWO	IMPERFECT	Total
Mean number	36.3 (34.5) *	1.2	12.5	50
Percentage	72.7% (69.0%) *	2.3%	25.0%	100%

* Number and percentage in the parenthesis are of ONE-TO-ONE that has minimum ΣD.

more than the others.

Also same as before, about ONE-TO-ONE obtained in the experiment, the relation between the inter-element distance and the correspondence of dots was examined. Between two three-dot patterns, six kinds of ONE-TO-ONE are possible. In each of 50 sets of stimuli, sum of distances between matched dots (ΣD) was calculated for each of six kinds of ONE-TO-ONE, and ΣD of ONE-TO-ONE obtained experimentally was compared with those of the other five. It was found that ninty-five percent of ONE-TO-ONE obtained in the experiment had smaller ΣD than the others, which indicates that out of six kinds of ONE-TO-ONE that are possible in each stimulus the one of minimum ΣD is likely to be obtained.

As a whole, the results obtained here with naive subjects are consistent with those in the previous study with experienced subjects.

EXP. 2

METHOD

Also in this experiment, the three—dot patterns were used as stimulus. In each pattern three dots had different luminance. The luminance used was 5.5, 11.6, and 23.2 nit. The luminance of background was 2.3 nit. Fifty pairs of three-dot patterns were prepared be-

fore the experiment. Except the luminance of stimuli, the method was the same as in Exp. 1.

RESULTS AND DISCUSSION

Mean numbers and percentages of the three types of correspondence obtained in Exp. 2 are shown in Table 2. Also in this experiment ONE-TO-ONE was obtained more than the other two. But in comparison with the results of Exp. 1, ONE-TO-ONE emerged less and

Table 2. Mean numbers and percentages of three types of correspondence obtained in Exp. 2.

Type of correspondence	ONE-TO-ONE	ONE-TO-TWO	IMPERFECT	Total
Mean number	33.5 (31.5) *	1.0	15.5	50
Percentage	67.0% (63.0%) *	2.0%	31.0%	100%

* Number and percentage in the parenthesis are of ONE-TO-ONE that has minimum ΣD.

IMPERFECT more. This result indicates that the variation of stimulus luminance impedes the emergence of ONE-TO-ONE.

In the same way as before, the relation between inter-dot distance and correspondence of dots was examined. And also here, the preference for the correspondence of minium ΣD was observed. Ninty-four percent of ONE-TO-ONE obtained in the experiment had smaller ΣD than the other five in each stimulus.

When three dots in each pattern have different luminance, six kinds of ONE-TO-ONE which are possible in each stimulus can be classified into three categories: ONE-TO-ONE which has only the pairs of dots of the same luminance (SAME), the one which has both the pairs of dots of the same luminance and of different luminance (MIXED), and the one which has only the pairs of dots of different luminance (DIFF). Table 3 shows mean numbers and percentages of these three types of ONE-TO-ONE obtained in the experiment. Frequency of SAME was not higher than those of the other two. So it can not be said that ONE-TO-ONE which contains the pairs of dots of the same luminance is more likely to appear than the others.

Although little influence of stimulus luminance on the correspondence process was found, the scrutiny of the results revealed that the luminance affected the emergence of ONE-TO-ONE of minimum ΣD. First, numbers of stimuli whose ONE-TO-ONE of minimum ΣD belonged

Table 3. Mean numbers and percentages of three types of ONE-TO-ONE obtained in the experiment.

Type of ONE-TO-ONE	SAME	MIXED	DIFF	Total
Mean number	5.7	19.3	8.5	33.5
Percentage	17.0%	57.6%	25.4%	100%

to each of three types of ONE-TO-ONE (ⓐ) were obtained. They are shown in the upper row of Table 4. In the middle row of it, mean numbers of ONE-TO-ONE having minimum ΣD of each type that was actually obtained in the experiment (ⓑ) are given. Then the ratio of ⓑ to ⓐ was calculated. This ratio signifies the percentage of emergence of ONE-TO-ONE having minimal ΣD of each type. They are shown in the lower row of Table 4. The percentage of emergence was highest in SAME and lowest in DIFF. From this result we can say that in each stimulus ONE-TO-ONE of minimum ΣD is more likely to be obtained when it contains more pairs of dots of the same luminance.

Table 4. Influence of luminance on the emergence of ONE-TO-ONE of minimum ΣD.

Type of ONE-TO-ONE	SAME	MIXED	DIFF	Total
Number of stimulus (ⓐ)	6.5*	27.5*	16	50
Mean number of obtained ONE-TO-ONE (ⓑ)	4.7	18.5	8.3	31.5
Percentage of emergence (ⓑ/ⓐ)	72%	67%	52%	

* When N kinds of ONE-TO-ONE that have minimum ΣD exist in a stimulus, each of them was counted as 1/N.

Also IMPERFECT can be classified into three types by luminance: IMPERFECT that has only the pairs of dots of the same luminance (SAME), the one that has both the pairs of dots of the same luminance and of different luminance (MIXED), and the one that has only the pairs of dots of different luminance (DIFF). Mean numbers and percentages of three types of IMPERFECT are shown in Table 5. DIFF was obtained most and SAME least. In IMPERFECT also there found little influence of luminance on the correspondence of stimulus dots.

Table 5. Mean numbers and percentages of three types of IMPERFECT obtained in the experiment.

Type of IMPERFECT	SAME	MIXED	DIFF	Total
Mean number	2.2	5.3	8.0	15.5
Percentage	14.2%	34.2%	51.6%	100%

When each stimulus contains several elements, it is possible that many kinds of motion percept appear depending on the correspondence of elements between stimuli. It is known that many factors affect the correspondence process (Baker & Braddick, 1982a, 1982b, 1985; Lappin & Bell, 1976; Pantle & Petersik, 1980; Petersik & Pantle 1979; Pomerantz, 1979). And several researches reported that each stimulus element tended to be matched with the other elements that have the same or similar characteristics (Navon, 1976; Ullman, 1980; Mack et al., 1989).

In this study the influence of stimulus luminance on the correspondence process was exa-

mined. It was found that the stimulus luminance affects the emergence of apparent movement. ONE-TO-ONE was perceived more frequently when the elements had the same luminance than when they had not. On the other hand, the luminance had little influence on the correspondence of stimulus elements. The apparent movement was perceived between dots of different luminance as well as between those of the same luminance. Compared to the inter-element distance, the stimulus luminance is conceived to be the subsidiary factor in determining the correspondence of stimulus elements. In the case that the stimulus patterns do not have the same or similar spatial configuration, as in the experiments reported here, the correspondence of stimulus elements is mainly determined by inter-element distance, and the influence of the other facters is very little.

The perception of apparent movement is a constructive process that makes up for the gap or discontinuity between stimuli (Neisser, 1967). And the load of the construction is supposed to be proportional to the spatial and temporal gap. The dominance of ONE-TO-ONE of minimum ΣD is conceived to represent the preference of the visual system for lighter load of construction. The irrelevance of stimulus luminance seems to indicate that the difference in it does not increase so much the load of the constructive process.

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