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ENTRAINED MOTION IS AFFECTED BY THE NUMBER OF ENTRAINING STIMULI AND EQUALITY IN THE MOVING DISTANCE OF STIMULI

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Ten undergraduate students took part in two experiments of entrained motion, a type of apparent motion, in which a test stimulus (TS), blinking alone, appears to move entrained by the apparent motion of entraining stimuli (ESs) in the display. The subjects rated the motion of the TS under conditions varying in the number of ESs and the moving distances of the TS and ESs. The first experiment showed that the rating of motion increased with the number of ESs. The second experiment showed that the rating was larger when the moving distance of the TS was equal to the distances of ESs than when not. The rating was indifferent to either of the moving distances of the TS and ESs. The results indicate that entrained motion is determined not only by ESs but also by the spatial configuration of all the elements in the display.

Key words: visual apparent motion, entrained motion, spatial arrangement, distance

When the first frame consisting of a single dot (namely test stimulus, TS) and a gray rectangle is alternated repeatedly with the second frame consisting of only the rectangle, one perceives the dot to blink. However, when a few dots, namely entraining stimuli (ESs), are added to the first and second frames so that the dots might be shifted by the same distance in the same direction between the frames, as is shown in Fig. 1, we perceive not only the added dots to move, but also the dot (TS) that appears to blink alone, to move back and forth between the positions of the TS and the rectangle. This phenomenon is called entrained motion and it is a type of apparent motion (Ramachandran & Anstis, 1986). Entrained motion was found to follow the trajectory of the motion of ESs (Anstis & Ramachandran, 1986). The purpose of the study is to obtain additional experimental data on entrained motion and then to examine it in more detail.

Entrained motion is a type of apparent motion because it does not have its real moving correspondence in the physical world. It has been well known that the spatial configuration among elements in a stimulus display is a factor in producing apparent motion (Anstis, 1978; Graham, 1951; Ramachandran & Anstis, 1986; Watanabe, 1981, 1994). The number of elements and their spatial arrangement in the display are important for designing the configuration of them. To produce entrained motion, the existence of the ES is essential to produce entrained motion. Due to this, does

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increasing the ES result in strengthening the motion? And does locating ESs near to the TS in a frame, result in affecting the motion more than locating them far from the TS? We, therefore, controlled the number of ESs and the distance between the TS and each ES in the first experiment. The subjects were asked to rate the motion of the TS by reporting a number between 0 and 5 depending on the appearance of motion.

There are many experimental data supporting that the moving distance of the stimulus itself between the frames, is a factor in producing apparent motion (Anstis, 1978; Graham, 1951; Watanabe, 1981, 1994). How do the moving distances of the TS and ESs influence the appearance of entrained motion? Does a long moving distance of the TS itself result in a better or worse motion than the short distance? Does the long moving distance of the ES result in a better or worse motion of the TS than the short distance? Is the motion affected by the equality in the moving distances of the TS and ESs? We, therefore, controlled the moving distances of the TS and ESs in the second experiment. We prepared four conditions by varying the moving distances of the TS and ESs short or long, respectively. The subjects were asked to rate the motion of the TS in the same way as in the first experiment. In this way, we further examined the effect of the spatial arrangement of the TS and ESs on entrained motion.

Experiment 1

This experiment was designed to examine the effects of the number of ESs and the distance between the TS and each ES on entrained motion.

Method

Subjects: The subjects were 10 male undergraduates from Kinki University, Kyushu. All had normal or corrected-to-normal vision and were unfamiliar with the experiment of entrained motion.

Apparatus and stimuli: The stimuli were presented on an AMIGA 4000 computer screen placed about 57 cm away from the subjects. Each stimulus consisted of three frames. The first frame basically consisted of a white dot (0.8° diameter in visual angle) as a TS, a light gray rectangle (1.9° in height and 1.3° in width), and an orange dot (0.3° in diameter) as a fixation point (FP) against a black background. The intercentral distance was 4.6° between the TS and the rectangle, and 2.5° between the rectangle and the FP. One or five of ESs, the same dots in color and size as the TS, were added to the frame, depending on the condition of arrangement. The second frame consisting of only the rectangle and the FP, was prepared to insert inter-stimulus interval (ISI) between the first and third frames. The third frame was the same as the first one except that the TS was deleted and ESs were shifted by 4.6° to the right of the original spot of each ES when the frame included ESs. The rectangle and the FP were fixed in the same position for all the frames. The luminances of the TS, ES, FP, the rectangle, and the background were 115.8, 115.8, 52.2, 53.3, and 0.5 cd/m^2, respectively.

We prepared five conditions of arrangement by varying the number of ESs and the distances among the TS and ESs in the frame. No dot was added in the N0 condition. One ES was added near to the TS in the N1 condition, while five ESs were added similarly in the N5 condition. One ES was added far from the TS in the F1 condition, while five ESs were added similarly in the F5 condition. The distance was 3.5° in visual angle between the TS and ES for N1, while the distance was 7° for F1. The distances for F5 among the TS and each of ESs were expanded so that the distances were twice as those for N5 while the relations among TS and ESs are kept unchanged.

Procedure: The first and third frames were alternated at the rate of 6 frames per second (fps) with the second frame intervening between them until the subjects reported the rating on the motion for each trial.

The subjects were given five trials, one for each of the five conditions: N0, N1, F1, N5, and F5. This was done after a 5-minute dark adaptation during which they were given an instruction and a practice in each of the five conditions. To measure the entrained motion, we used a rating method similar to that used by Ohmura to measure apparent motion (Ohmura, 1982, 1986). The subjects rated the appearance of the motion between the TS and the rectangle. They reported a "5" when they perceived a perfect and smooth motion from the TS to the rectangle, a "0" when they perceived no motion, and reported a "1," "2," "3," or "4" depending on the appearance of the motion they perceived. They were asked to keep their eyes on the FP during the trial. The subject was tested individually in the dark room. The order effect was counterbalanced across subjects.

Results

Table 1 shows the ratings on the appearance of entrained motion averaged for 10 subjects for each condition of arrangement. As seen in the table, motion is perceived in all the conditions except for N0. The rating is larger in the N5 and F5 conditions than in the N1 and F1 conditions. There is little difference between the N1 and F1 conditions, and between the N5 and F5 conditions.

The data of the rating were examined using a one-way analysis of variance. The main effect of arrangement was significant ($F(4, 36)=56.48$, $p<.01$). The subordinate test showed that there was a significant difference between each pair of conditions, except between N1 and F1, N1 and F5, as well as N5 and F5 (LSD$=0.984$, $p<.01$). The results showed that the number of ESs affected entrained motion and that the distance between the TS and each ES did not.

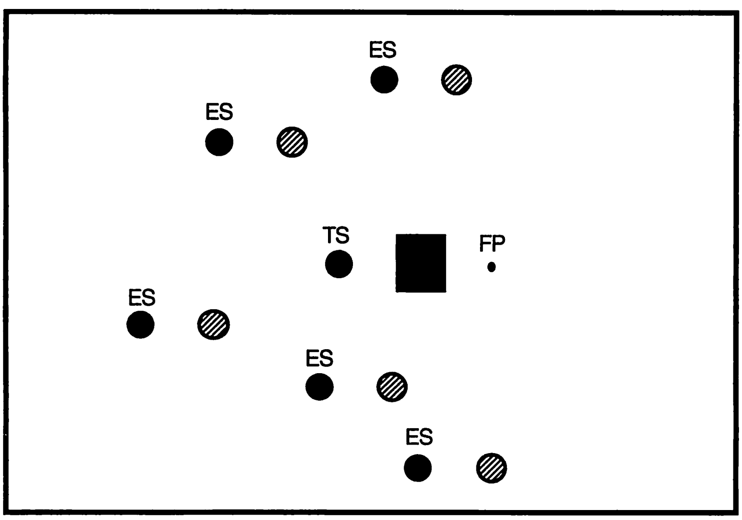

Fig. 1. A sample of the stimuli similar to those used in Experiment 1.

Note: The first frame consisted of a dot as a test stimulus (TS), and dots as entraining stimuli (ESs), which were solid black. The second frame consisted of each counterpart of ESs in the first frame, striped obliquely, shifted by an equal distance rightward. A rectangle and a fixation point (FP) were presented throughout the experiment. When two frames were alternated repeatedly, the TS appeared to move back and forth between the positions of the TS and the rectangle entrained by apparent motion of ESs, though the TS did not have its counterpart in the second frame.

Table 1. Means and Standard Deviations of Rating on Entrained Motion (Experiment 1)

	N0	N1	F1	N5	F5
Mean	0	3.70	3.10	4.70	4.20
SD	0	0.95	1.37	0.48	0.63

Experiment 2

This experiment was designed to examine the effect of the moving distances of the TS and ESs on entrained motion.

Method

Subjects: The subjects were the same undergraduates who participated in Experiment 1.

Apparatus and stimuli: The stimuli were presented on an AMIGA 4000 computer screen in the same way as in the first experiment. Each stimulus consisted of three frames. The first frame consisted of a TS, a rectangle, two ESs, and an FP. The TS and ESs were arranged in a vertical line with the TS located in the middle of them. The distance between the TS and each ES was 6.6° in visual angle. The second frame was the same as in the first experiment. The third frame was the same as the first one except that the TS was deleted and ESs were shifted rightward by the equal distance, 2° or 6° in visual angle, depending on the condition of arrangement. The rectangle and the FP were fixed in the same position for all the frames. The TS, rectangle, ESs and FP were the same in color, size and luminance as in the first experiment.

We prepared four conditions of arrangement by varying the moving distances of the TS and ES between the first and third frames, short or long, namely 2° or 6° in visual angle. The intercentral distance between the TS and the rectangle, and the distances of ESs between the frames, were 2° and 2° in visual angle for ST-SE, 2° and 6° for ST-LE, 6° and 2° for LT-SE, as well as 6° and 6° for LT-LE, respectively.

Procedure: The three frames were presented in the same way as in the first experiment until the subjects reported the rating of the motion for each trial. The subjects were provided with four trials, one for each of the four conditions: ST-SE, ST-LE, LT-SE, and LT-LE. The procedure was the same as in the first experiment except for the change above.

Results

Table 2 shows the ratings on the appearance of entrained motion averaged for 10 subjects for each condition of arrangement. As seen in the table, the rating is larger in the ST-SE and LT-LE conditions than in the ST-LE and LT-SE conditions. There is little difference between the ST-SE and LT-LE conditions.

The data of the rating were examined using a one-way analysis of variance. The main effect of arrangement was significant ($F(3, 27)=14.86$, $p<.01$). The subordinate test showed that there was a significant difference between each pair of conditions except between ST-SE and LT-LE, and ST-LE and LT-SE (LSD=1.66, $p<.01$). The results showed that the moving distance of the TS and ESs affected entrained motion.

Table 2. Means and Standard Deviations of Rating on Entrained Motion (Experiment 2)

	ST-SE	ST-LE	LT-SE	LT-LE
Mean	4.50	1.50	2.60	4.90
SD	0.85	1.58	1.90	0.32

Discussion

The purpose of this study was to obtain experimental data on entrained motion and examine it in more detail. Two experiments were performed to understand entrained motion from the viewpoint of the spatial configuration. The index was the rating that the subjects provided on the appearance of motion of the TS throughout the experiments.

In the first experiment, we prepared five conditions: N0, N1, F1, N5, and F5. There was no ES in the N0 condition, while there was one in the N1 and F1 conditions, and five in the N5 and F5 conditions. ESs were located near to the TS in the N1 and N5 conditions, while far from the TS in the F1 and F5 conditions. The results were as follows: The TS did not appear to move at all in the N0 condition while it appeared to move in the N1, F1, N5, and F5 conditions. The rating was larger in the N5 and F5 conditions than in the F1 condition, while larger in the N5 condition than in the N1 condition. There was no difference between the N1 and F1 conditions as well as between the N5 and F5 conditions. The results showed that one ES is enough to make us perceive the TS to move, and that increasing the ES improves the perception of the motion.

We did not obtain a clear effect due to the distance between the TS and each ES in the display. However, we obtained the following results:The rating was a little larger in the N1 condition than in the F1 condition though we obtained no significance between the conditions. Similarly, the rating was a little larger in the N5 condition than in the F5 condition, though we obtained no significance between the conditions, either. In addition, because of the effect of the distance, the rating for F5 was not significantly larger than that for N1 despite the difference in the number of ESs. The results suggest the possibility that the distance between the TS and each ES may affect entrained motion. Near ESs might affect the entrained motion of the TS more than distant ones. To make the effect of the distance clear, we needed an additional experimental study.

In the second experiment, we prepared four conditions: ST-SE, ST-LE, LT-SE, and LT-LE. The moving distances of the TS and ES were both short in the ST-SE condition, while they were both long in the LT-LE condition. The distance of the TS was short and that of ES long in the ST-LE condition, while long and short, respectively, in the LT-SE condition. The rating was larger in the ST-SE and LT-LE conditions than in the LT-SE and ST-LE conditions. There was no difference between the ST-SE and LT-LE conditions and between the ST-LE and LT-SE conditions. The results show that how long ESs or TS move is unimportant when we perceive entrained motion over the distance of 2° or 6° in visual angle. The importance lies on whether or not the TS and ESs move by an equal distance. The equality in the moving distances of the TS and ESs makes us perceive smooth and good entrained motion.

The results give us a new idea about entrained motion. Entrained motion is a phenomenon in which we perceive apparent motion in the TS, entrained by apparent motion in stimuli, namely ESs, surrounding the TS in the display, of which we demonstrated in the first experiment. Though entrained motion is produced by the ES in the display, it is not determined only by the ES. Entrained motion is determined not by either of the moving distances of the ES and TS but by the relation between them, which we demonstrated in the second experiment. In summary, entrained motion is determined by the spatial configuration of all elements in the display. Here, the results on entrained motion cause us to remember that the spatial configuration including whole elements in the display is important to determine apparent motion.

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