Psychologia, 1994, 37, 248–253

EFFECTS OF INTERCENTRAL AND INTERCONTOUR DISTANCES ON VISUAL STREAM SEGREGATION

Isao WATANABE*

Kinki University, Japan

Two experiments were performed to examine which is important, intercentral or intercontour distance between the stimuli, to affect visual stream segregation (VISS). VISS is a phenomenon of two sets of apparent motion, which is seen among four lights, A, B, C, D on a vertical row presented at a fast rate alternately in the order of A, C, B, and D. Eight undergraduates were required to find the upper limits of the interstimulus interval (ISI) for producing VISS under each condition of intercentral and intercontour distances. The ISI increased with intercentral distance, but was constant irrespective of the intercontour distance. The results show that it is not intercontour but intercentral distance between the stimuli that is important to decide VISS and apparent motion between two stimuli.

When two stimuli were presented alternately in two positions with a short interstimulus interval (ISI), an apparent motion was seen between them. Spatial distance between the stimuli is an important factor to decide apparent motion, together with duration of the stimuli, ISI between them, and their intensity (Graham, 1951; Korte, 1915). Korte's third law stated that the ISI between the stimuli increases with the spatial distance between them to produce optimal apparent motion.

What do we mean exactly by the spatial distance between the stimuli? Do we mean the intercentral distance between the stimuli or the intercontour distance? It is not necessary to differentiate between them, when we deal with apparent motion between the two stimuli. This is because we can complete the spatial arrangement without clear differentiation between the distances. Though the students used the intercentral distance to describe the spatial arrangement in apparent motion between the two stimuli, they sometimes used the intercontour distance, too. In dealing with apparent motion between the two stimuli, they have still not examined the differentiation between the distances.

However, it is necessary to differentiate between these distances, when we deal with apparent motion among more than two stimuli. This is because we cannot locate a third stimulus without locating exactly the first and second stimuli.

"Visual stream segregation (VISS)" is a new type of apparent motion among four stimuli. Four lights, A, B, C, and D, which were located in a vertical row in that order, were flashed alternately in the order, A, C, B, and D. When they were flashed at a slow rate, a light is seen moving back and forth among the four positions in the presented order. When they were flashed at a faster rate, two lights were seen moving, one between positions of A and B, and the other between those of C and D.

* Requests for reprints should be sent to Isao Watanabe, Department of Psychology, University of California at San Diego, La Jolla, CA 92093-0109, U.S.A.

The phenomenon obtained at a faster rate was named VISS by Bregman and Achim (1973).

VISS followed Korte's second law that states the relation between the intensity and the ISI to produce optimal apparent motion (Watanabe, 1992, 1993). It also followed Korte's fourth law that states the relation between the duration and the ISI to produce optimal apparent motion (Ohmura, 1982, 1986). On the basis of these results, Ohmura concluded that VISS was functionally equivalent to apparent motion, and that it was, in form, regarded as a compound phenomenon consisting of two apparent motions.

Watanabe (1981) examined the effects of the spatial distances among the four lights, A, B, C and D on VISS. He measured the upper limits of ISI to produce VISS, namely, the transition point of ISI at which a change occurred between VISS and apparent motion in the presented order. He obtained the results that the ISI increased with distance between the positions of B and C, namely, the shortest distance between the two apparent motions. The distance between B and C is important for producing VISS, while the distances between A and B, between C and D, and between A and C are not. Which one affected VISS in Watanabe (1981), the intercentral distance between B and C or the intercontour distance?

The present study examines the effects of spatial distance on VISS, using the same method as Watanabe (1981). The spatial distance was varied either in intercentral distance or intercontour distance between B and C in the above-mentioned VISS situation. The upper limits of ISI were measured to produce VISS for each condition of the spatial distances. On the basis of the results, the effect of spatial distance is discussed not only for VISS but also for apparent motion in general.

Experiment 1

This experiment examined the effect of the intercontour distance between the stimuli on VISS with the intercentral distance constant. The upper limits of ISI for producing VISS were measured following the method of adjustment, where the intercontour distance between B and C was varied in three levels.

Method

Subjects: The subjects were eight (three female and five male) undergraduates from Kinki University in Kyushu. All had normal or corrected-to-normal vision. Four of them were naive to the experiment of apparent motion, and the rest were acquainted with the experiment.

A set of four electroluminescent (EL) panels was flashed successively, using a power source for EL panels. The timing of flashings was controlled by a two-channel digital timer, a one-channel remote-controlled timer, and a time-controller. Four panels were flashed with the durations equally constant, the ISIs between them equal, and the intercycle interval (ICI) constant. The ISIs were adjustable by using two buttons of a switch on the remote-controlled timer. The time adjusted by the subject was displayed digitally in milliseconds to the experimenter.

Stimulus display: The stimulus display consisted of a set of four rectangles of EL panels, A, B, C, and D, which were arranged in a vertical row as shown in Fig. 1. The intercentral distances were constantly 1.43° of visual angle between A and B, and between C and D, and 2.86° between B and C. The intercontour distance between B and C was changed in three ways. The distance was 1.81° of visual angle in narrow (N) condition, 2.34° in medium (M) condition, and 2.81° in wide (W) condition. The intercontour distances also changed between A and B and between C and D in accordance with that between B and C. The widths of the panels were changed to keep the square measure of the panel constant for all the conditions. The widths of the panels were 0.05° of visual angle in N condition, 0.53° in M condition and 1.05° in W condition. A different set of panels was prepared for training. It was the same as in the three experimental conditions except that each panel was a square. The panels were about 150 cd/m^2 in luminance. A green light-emitting diode was located in the middle between B and C as a fixation point. It was 0.14° of visual angle in diameter and 3 cd/m^2 in luminance.

Procedure: A set of four panels, which were stimuli, was flashed in the order A, C, B, and D, repeatedly. The duration was always 50 ms, while the ICI was always 500 ms from the offset of D to the onset of A. The subject sat at a table with his head located on a chin-rest, and observed binocularly the stimulus display 120 cm distant from him. He judged the appearance of the display, while staring at the fixation point. The experiment was performed in two sessions. The first session consisted of 3 tasks: training, observation, and adjustment. The second session consisted of adjustment task.

In the training task, a sequence of flashings of the set of panels was displayed to the subject. The subject was trained to understand a differentiation between VISS and apparent motion in the order of presentation. He was required to judge whether the apparent sequence of flashings is similar to VISS or not, under some ISIs between 30 ms and 250 ms. After a few trials, when the subject constantly reported perceiving VISS in shorter ISI and not in longer ISI, the task ended. The stimulus display for training was used for this task.

In the observation task, the sequence of flashings was displayed, while the ISI was varied continuously from 5 ms to 250 ms or from 250 ms to 5 ms by the experimenter. The subject observed the change of the appearance of the flashings caused by a change of the ISI under each condition of distance.

In the adjustment task, the subject was asked to find the transition point of ISI at which a change occurred between VISS and apparent motion in the order of presentation. A trial consisted of an ascending series and a descending series. In the ascending series, the subject lengthened the ISI starting from 5 ms until VISS ceased to appear, using the buttons of a switch on the remote-controlled timer. In the descending series, he shortened the ISI starting from 250 ms until VISS began to appear. The upper limit of ISI for producing VISS was the average of the ascending series and descending series. The transition point was considered a threshold.

The adjustment task consisted of six blocks of three trials with a trial for each distance condition per block in random order. A two-minute rest was given between blocks. The order effect was counterbalanced among blocks and across subjects. Ten minutes were given for dark adaptation before the

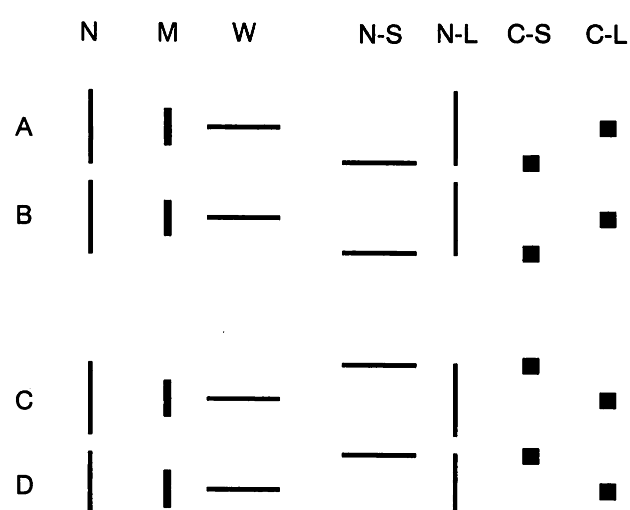

Fig. 1. Stimulus displays used in Experiment 1 (N, M, and W) and Experiment 2 (N-S, N-L, C-S, and C-L).

Table 1. Means and Standard Deviations for the Upper Limits of ISI (in Milliseconds) for Perceiving VISS under each Condition of Intercontour Distance (Experiment 1)

	N	M	W
Mean	99	98	95
SD	20	20	18

experiment. The subject was tested individually in a dark room.

Results

The first block was practice trials and the other were test trials. Mean upper limits of ISI were used as data after being averaged for each subject through five test trials in each distance condition. Table 1 shows the mean ISIs averaged for eight subjects in each distance condition. As is seen in Table 1, there was no difference in ISI among the three conditions. The ISI data were examined by a one-way analysis of variance. The main effect of size was not significant ($F(2, 14)=1.05$, $p>.10$).

Experiment 2

This experiment examined the effects of the intercontour and intercentral distances between the stimuli on VISS. The intercontour and intercentral distances were both varied between B and C. The upper limits of ISI for perceiving VISS were measured following the same method as in the first experiment under each condition of intercontour and intercentral distances.

Method

Subjects: The subjects were eight (two female and six male) undergraduates from Kinki University in Kyushu. All had normal or corrected-to-normal vision. Four of them were naive as to the experiment of apparent motion, and the rest were acquainted with the experiment.

Apparatus: The apparatus was the same as used in the first experiment.

Stimulus display: A set of four rectangles of EL panels was used as a stimulus display. It was similar to that used in the first experiment. Four conditions were prepared as shown in Fig. 1. Intercontour and intercentral distances between B and C were as follows: 1.81° of visual angle and 1.86° for narrow-short (N-S) condition, 1.81° and 2.86° for narrow-long (N-L) condition, 1.64° and 1.86° for control-short (C-S) condition, and 2.64° and 2.86° for control-long (C-L) condition. The square measure of each panel was constant throughout the four conditions. The width of the panels was 1.05° of visual angle for N-S condition and 0.05° for N-L condition. The panels were squares, each side 0.22° of visual angle for C-S and C-L conditions. The same set of panels for training was used as in the first experiment. A fixation point was located in the same way as in the first experiment. It was the same light-emitting diode as in the first experiment.

Procedure: The set of four panels, which were stimuli, was flashed in the same way as in the first

Table 2. Means and Standard Deviations for the Upper Limits of ISI (in Milliseconds) for Perceiving VISS under each Condition of Distance (Experiment 2)

	N-S	N-L	C-S	C-L
Mean	91	103	92	105
SD	21	23	21	22

experiment. The subject was tested in a set of 3 tasks: training, observation, and adjustment. The adjustment task consisted of six blocks of four trials, a trial for each of the four conditions in random order.

The procedure was the same as in the first experiment except for the specifications given above.

Results

The first block was practice trials and the other were test trials. Mean upper limits of ISI were used as data after being averaged for each subject through the five test trials in each condition. Table 2 shows the mean ISIs averaged for eight subjects in each condition of distance. As is seen in Table 2, ISI was longer for the long intercentral distance conditions (N-L and C-L) than for short distance conditions (N-S and C-S). There was no difference in the ISI due to the intercontour distance. The ISI for N-S was equal to that for C-S, while the ISI for N-L was equal to that for C-L.

The ISI data were examined by a one-way analysis of variance. A significant main effect of distance was obtained ($F(3, 21)=14.94$, $p<.001$). The lower test was performed on the data by using the least significant difference. A significant difference was obtained between N-S and N-L, between N-S and C-L, between N-L and C-S, and between C-S and C-L ($LSD=7.45$, $p<.01$). No difference was obtained between N-S and C-S and between N-L and C-L ($LSD=4.57$, $p>.10$).

Discussion

The purpose of the present study was to examine the effects of the intercentral and intercontour distances between the stimuli on VISS. The distance between B and C was varied in the VISS configuration of Watanabe (1981). The upper limits of the ISI were measured to produce VISS for each condition of the distances.

In the first experiment, the intercontour distance between B and C was varied in three conditions of N, M, and W with the intercentral distance constant. The intercontour distances were 1.81° (N) of visual angle, 2.34° (M), and 2.81° (W), with the intercentral distance in 1.43° constant. In the spatial arrangement for the experiment, the change in the intercontour distances between B and C also introduced the change in the other distances among the four stimuli. However, only the distance between B and C is important for producing VISS, while any other distances among the stimuli are not (Watanabe, 1981). Therefore, if any difference was obtained, it would be ascribed to the effect of distance between B and C.

The obtained result was that there was no difference in the ISI due to the intercontour distance. According to Watanabe (1981), a 1° of visual angle difference in distance was enough to produce a significant difference in the ISI. In this study, the difference in intercontour distance was 1° between N and W conditions. However, the difference did not result in a differential effect. The results indicate that intercontour distance does not have any effect on VISS as far as the intercentral distance is constant.

There is another possible explanation for this. To keep the areas of the squares constant, the shape of the stimulus was different among the conditions. The difference in shape may also have affected the ISI and produced such a result.

The second experiment was designed to examine the possibility and clarify the effects of both intercentral and intercontour distances between B and C on VISS. The intercontour distance was 1.81° of visual angle in both N-S and N-L conditions, 1.64° in C-S condition, and 2.64° in C-L condition. The intercentral distance was 1.86° of visual angle in both N-S and C-S conditions, and 2.86° in both N-L and C-L conditions. The only differential effect was due to the intercentral distance. The ISI for N-L was longer than that for N-S, though both conditions were equal in the intercontour distance. The ISI for C-L was longer than that for C-S. The ISI for C-L was equal to that for N-L, though the intercontour distance for C-L was longer than that for N-L. The results indicate that the ISI increases with the intercentral distance between B and C to produce VISS and is indifferent to the intercontour distance.

Did the shape of the stimulus affect VISS? The ISI for N-S was equal to that for C-S, while the ISI for N-L was equal to that for C-L. Such a result was obtained irrespective of the fact that the shape of the stimuli was different between N-S and C-S and between N-L and C-L. That result is a possible answer for what was proposed in the first experiment. It is the only clear effect of the intercentral distance in spite of the differences in shape among the conditions. This result demonstrates that the obtained result in the first experiment was not due to the difference in shape. It also strengthens the conclusion that the ISI was indifferent to the intercontour distance.

When we discuss apparent motion, it usually means apparent motion between the two stimuli. However, the apparent motion is not an easy experiment to do, because it takes a long time to train the subjects to differentiate among the phenomena prior to the experiment. On the other hand, VISS is a type of apparent motion easy do deal with and is sensitive to the experimental conditions, following the method used here. Direct data has not yet been obtained concerning the effects of intercentral and intercontour distances on apparent motion between the two stimuli. According to the present data on VISS, the apparent motion is affected in general by only the intercentral distance but not by the intercontour distance.

REFERENCES

Bregman, A. S., & Achim, A. 1973. Visual stream segregation. *Perception and Psychophysics,* **13**, 451–454.

Graham, C. H. 1951. Visual perception. In S. S. Stevens (Ed.), *Handbook of experimental psychology.* New York: Wiley. Pp. 868–920.

Korte, A. 1915. Kinematoskopische Untersuchungen. *Zeitschrift für Psychologie,* **72**, 193–296.

Ohmura, H. 1982. Visual stream segregation and β movement. *Japanese Journal of Psychology,* **53**, 50–53. (In Japanese with English abstract)

Ohmura, H. 1986. The role of stimulus intensity, color, and form in visual stream segregation. *Japanese Psychological Research,* **28**, 21–29.

Watanabe, I. 1981. The effect of the spatial distance upon visual stream segregation. *Japanese Journal of Psychology,* **52**, 57–60. (In Japanese with English abstract)

Watanabe, I. 1992. Effect of stimulus intensity on visual stream segregation. *Japanese Journal of Psychology,* **63**, 346–349. (In Japanese with English abstract)

Watanabe, I. 1993. Effects of size and luminance of stimulus on visual stream segregation. *Japanese Psychological Research,* **35**, 161–171.

(*Manuscript received May 10, 1994*)