The Poggendorff Illusion under Stereopsis

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THE POGGENDORFF ILLUSION UNDER STEREOPSIS

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When the rectangle was displaced in front of the oblique line in the Poggendorff figure, the illusion was found to reduce largely in binocular viewing. To investigate the underlying mechanism of this phenomenon, three experiments were carried out with total 33 undergraduate *Ss* and the psychophysical functions between the magnitude of the illusion and the depth separation were obtained when the rectangle was oriented either vertically or horizontally, namely in the vertical and horizontal condition.

It was found that the functions of the two conditions were different in shape and that the decrease of the illusion was smaller in the horizontal condition. However, when the part of the oblique line which was interrupted by the rectangle from both the eyes was kept constant in width irrespective of the depth separation, such anisotropy disappeared and the functions of both the conditions showed a decreasing tendency of the illusion.

From these results, it was found that perception of the oblique line parts falling on "undetermined areas" in binocular single vision played an important role in reduction of the illusion in the vertical condition. The other findings were discussed in the context of the flow diagram of binocular vision.

Introduction

Focusing their considerations on the inferential or feedfoward-like aspects of perception, Maruyama & Iwasaki (1973) picked up some perceptual phenomena and gave a general term "prospective perception" to them.

One example they cited was the Poggendorff illusion. In a situation such as seeing a tree over and beyond an interruption, we somewhat infer or anticipate the hidden part of the tree to be there from the visible part. Although the same perceptual processing should occur in the Poggendorff figure, the segments of the oblique line bisected by the rectangle are always perceptually misaligned.

However, an interesting phenomenon was discovered this time in the Poggendorff illusion. If the rectangle is displaced in front of the oblique line, the magnitude of the illusion reduces dramatically in binocular viewing.

On the other hand, Julesz (1971) protrayed various illusory figures by random-dot stereograms and already pointed out that the illusion becomes reduced in most cases when stereoscopic depth separation is provided between the inducing figure and the test figure. Especially in the Poggendorff figure, the complete disappearance of the illusion has been reported.

The present study aimed at elucidating the machism underlying this phenomenon.

Experiment I

The purpose of Exp. I was to obtain the psychophysical functions between the magnitude of the illusion and the stereoscopic depth separation of the rectangle from the oblique line, when the rectangle is oriented either vertically (V-condition) or horizontally (H-condition).

Method

Subjects: Five undergraduate students were tested under each condition. A total of 10 *S*s had normal visual acuity and their stereopsis ability was checked up with Julesz's random-dot stereograms in advance of the experiment.

Apparatus: A haploscope (TKK Co. Ltd.) was employed in a dark room. The viewing distance was 52 cm. Each pattern of a stereogram was illuminated by a 4 w fluorescent lamp and binocularly superimposed on each other by two half-silvered mirrors set on the arms of the apparatus.

Stimuli: Tweleve stereograms were prepared for each condition.

In the V-condition, each half-image of a stereogram contained a solid black vertical rectangle ($1.1° \times 4.4°$) which bisected at 45° oblique line ($6.6° \times 0.33°$). Both of them were enclosed by a larger square frame ($5.5° \times 5.5°$). The rectangle carried four levels of crossed disparity from 0° to 0.69° in steps of 0.23° in visual angle. For the oblique line, three types of configuration were employed. In one type, the two segments of the oblique line were collinear, and in the other two types, they were physically misaligned, like ⁄ or ⁄⁄. The magnitude of physical misalignment was 0.22°, measured as the perpendicular distance between one segment and the extension of the other. The combination of the four levels of disparity carried by the rectangle and the three types of the oblique line configuration made 12 stereograms in total.

For the H-condition, other 12 stereograms were prepared, which were identical to those used in the V-condition except that the rectangle and the oblique line were rotated by 90° to left.

Procedure: Each stereogram was presented in random permutation six times to each *S*. The stereograms were shown until the *S* responded. On each presentation, the *S*s were asked to rate the perceived depth of the rectangle which appeared in front of the oblique line, using 6 numbers from +5 to 0. At the same time, they were also asked to rate the perceived misalignment of the oblique line segments, using 11 numbers from +5 to −5. The positive numbers were assigned to the misalignment in the ordinal direction of the illusion. The data were obtained from the last four judgements.

Results

Fig. 1 presents the mean misalignment judgements of 5 *S*s as a function of the perceived depth separation in each condition.

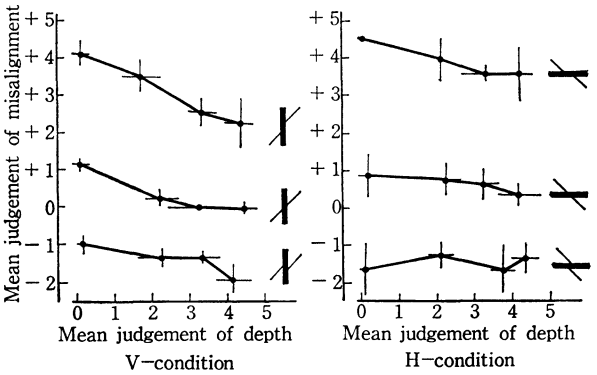


Fig. 1 Results of Exp. 1. Mean judgement of misalignment as a function of perceived depth separation.

In the V-condition, the curves of any types of the oblique line configuration show a clear decreasing tendency of the magnitude of the perceived misalignment with the increase of depth separation. Paticularly, the curve of the collinear type reveals that the illusion actually disappears when the disparity carried by the rectangle becomes larger than 0.46°. An analysis of variance applied to the misalignment judgements indicated that disparity was a significant treatment condition (F=56.44, df=3/12, p <0.001).

From the functions of the H-condition, the decreasing tendency of the perceived misalignment judgement can be also read, but this tendency is less clear as compared with the V-condition. Disparity was found to be not significant by application of an analysis of variance (F=3.39, df=3/12, p>0.05).

Thus the result of Exp. I confirmed that the Poggendorff illusion decreases or even disappears when the stereoscopic depth separation is provided. However, it also showed that the strength of this depth effect was influenced by the orientation of the rectangle that carried disparity.

Experiment II

In Exp. I, the rectangle was stereoscopically separated from the oblique line and a larger decrease of the illusion was found in the V-condition. Exp. II was carried out to obtain the functions between the magnitude of the illusion and the depth separation when the rectangle was actually displaced in front of the oblique line and to compare their shapes between the two conditions.

Method

Subjects: Sixteen undergraduate students who had normal and nearly equal visual acuity between the two eyes served as *S*s. A half of them were assigned to the V-condition and the other half to the H-condition.

Apparatus: A simple device was contrived so that the left half of the oblique line mounted on a white cardboard slide could be adjusted up and down along a vertical track behind the black rectangle (35.5×4 cm) with a controller at hand. The oblique line (0.3×32.8 cm) ran from top right to bottom left at a 30° angle. For the H-condition, the same apparatus was rotated by 90° to the left.

Procedure: *S* sat in front of the apparatus, placed his chin in the chin-rest, and binocularly viewed the illusion at a distance of 60 cm. The *S*s were asked to adjust the half of the oblique line so that it appeared to be line with the other half. During the adjustment, the *S*s were told to gaze at the center of the rectangle.

In each condition, the depth provided between the rectangle and the oblique line was 0 cm, 1 cm, 5 cm and 10 cm. The *S* made 10 settings at each depth level in the order of a Latin square design and the starting position for each setting was also alternated.

The magnitude of the illusion was defined as the perpendicular (or horizontal) distance between the two halves of the oblique line when they were judged to be collinear, measured in millimeters.

Results

The functions obtained under each condition are presented in Fig. 2. Each point of the functions of Fig. 2 is based on the average over 8 *S*s. The large SDs were derived from the individual difference in the absolute level of the illusion. The shapes of the functions were fairly consistent among *S*s.

With increasing depth separation, the curve of the V-condition shows a rapid decrease up to the 5 cm depth level and a slight increment at the 10 cm depth level. An analysis of variance for the magnitude of the illusion indicated that depth level was significant (F=11.23, df=3/21, p<0.01).

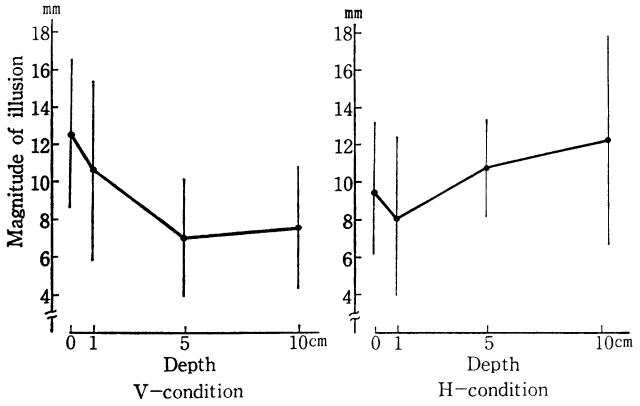


Fig. 2. Results of Exp. 2. Magnitude of illusion as a function of depth separation. The large SDs were derived mainly from the individual differences in the absolute level of the illusion magnitude. The trends were fairly consistent among *S*s.

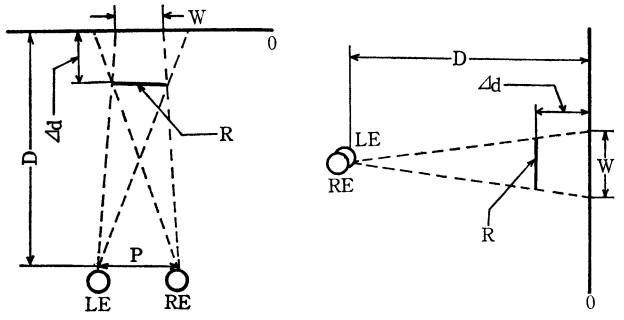
In contrast, the function of quite different shape was obtained under the H-condition. The curve reveals a notch at the 1 cm depth level and beyond it, gradually increases to the 10 cm depth level. An analysis of variance indicated that depth level was also significant ($F=4.75$, $df=3/21$, $p<0.05$) and by further application of the Newman-Keuls method, such significance was found to be derived from the difference between the 1 cm and 10 cm depth level.

Experiment III

The notch of the function obtained under the H-condition in the previous experiment seems to suggest that two antagonistic processes operated simultaneously in the condition. One of them possibly decreased the illusion with increasing depth separation and the other might operate to increase the illusion to the contrary.

Accordingly, the line of vision to the oblique line was investigated under each condition (Fig. 3). In the H-condition, the visual angle of the rectangle width becomes larger and larger with increasing depth. So the part of the oblique line which is interrupted by the rectangle increases in width gradually. In the case of the V-condition, the visual angle of the rectangle width also increases monocularly, but the line of vision can get into the interrupted part of the oblique line to some degree because each eye captures the oblique line from a different position. Consequently, the part of the oblique line which is interrupted from both the eyes and therefore requires perceptual interpolation can be expected to reduce in width, if the regions captured by only one eye are being perceived even in binocular single vision without receiving suppression.

It is known that there is a reasonable linear increase in the magnitude of the Poggendorff illusion with an increase in the distance between two parallels of the



$$R=\frac{W(D-\Delta d)+\Delta d\cdot P}{D}$$

V-condition

$$R=\frac{W(D-\Delta d)}{D}$$

H-condition

Fig. 3. Line of vision to oblique line. O, oblique line: R, rectangle width; D, viewing distance; d, depth provided between the rectangle and the oblique line; P, interpupillary distance; W, oblique line part interrupted from both the eyes.

rectangle (Weintraub & Krantz, 1971). Therefore, for those changes of the oblique line width interrupted from both the eyes, the illusion may be expected to decrease with depth separation in the V-condition, while to increase in the H-condition.

In Exp. III, the magnitude of the illusion was measured by keeping the interrupted part of the oblique line constant in width irrespective of the depth separation.

Method

Subjects: Tweleve undergraduate students served as *S*s. Using a within-subject design, each *S* participated in the two conditions. All *S*s had normal and nearly equal visual acuity between the two eyes.

Apparatus: The apparatus was the same device that was used in Exp. 2.

Experimental Conditions: In each condition, 4 levels of depth separation were provided between the rectangle and the oblique line. The rectangle width was also changed with those depth separations, as is shown in Table 1. The rectangle width at each depth level was calculated so that the width of the interrupted part of the oblique line from both the eyes was held constant 4 cm (measured as the perpendicular or horizontal distance W in Fig. 3), even when the depth separation was provided. The calculation formulae of W under each condition are shown at the bottom of Fig. 3. In calculation, the interpupillary distance was made 6 cm and the viewing distance was 60 cm. All rectangles were 26 cm in length. The size and the angle of the oblique line were the same as in Exp. II.

Procedure: A half of the *S*s were first tested under the V-condition and the other half under the H-condition. Except this point, the other procedures were identical with those of Exp. II.

Table 1. Experimental conditions of Exp. III. The rectangle width at each depth level was obtained from the calculation formulae in Fig. 3. (The figures below the second decimal were rounded.)

V-condition		H-condition	
Depth	Rectangle width	Depth	Rectangle width
0	4.0	0	4.0
1	4.0	1	3.9
5	4.2	5	3.7
10	4.3	10	3.3
	(Unit: cm)		(Unit: cm)

Results

The functions obtained under the two conditions are shown in Fig. 4. The inspection of Fig. 4 clearly shows that the two functions are almost the same in shape and absolute magnitude of the illusion. Thus the influence of the rectangle orientation

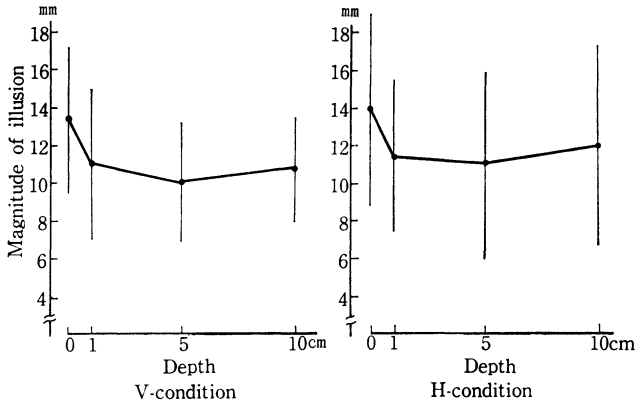


Fig. 4. Results of Exp. III. When the oblique line part interrupted from both the eyes was kept constant in width, the functions of the same shape were obtained. The large SDs were derived from the individual differences in the absolute level of the illusion magnitude.

was found to disappear, if the interrupted part of the oblique line which required perceptual interpolation remained constant in width irrespective of the depth separation.

However, both functions still show a clear decreasing tendency of the magnitude of the illusion with depth separation. A three-way analysis of variance (Depth×Rectangle Orientation×Subject) for the magnitude of the illusion indicated that only depth was a significant treatment condition ($F=6.14$ $df=3/33$, $p<0.005$). So the decrease of the Poggendorff illusion when depth separation is provided in binocular viewing can not be attributed only to the reduction of the oblique line width which requires perceptual interpolation.

Discussion

In the V-condition, when depth separation is provided, the parts impinging on only one eye are formed in the oblique line, as discussed before. Usually, binocularly uncorrelated areas are suppressed in binocular single vision owing to binocular rivalry. However, the uncorrelated regions which are formed after the shift of disparity carrying regions are called "undetermined areas" (Julesz, 1971), and always perceived behind correlated areas without receiving binocular rivalry.

So the reduction of the V-condition in the oblique line width which requires perceptual interpolation is guaranteed by the fact that the oblique line partially falls on the undetermined areas. Therefore, it can be considered that the perception of the oblique line parts falling on undetermined areas is responsible for the results of Exp. I which showed the influence of the rectangle orientation on the degree of the illusion decrease, and for Julesz's report that when stereoscopic depth separation was provided between the inducing and the test figure in various illusory figures, the complete disappearance of the illusion was found especially in the Poggendorff illusion.

In Exp. III, the obtained functions still showed a decreasing tendency of the illusion with depth separation, even when the oblique line width interrupted from both the eyes was kept constant. This result can be interpreted in the context of the adjacency principle (Gogel, 1975) which stresses the potency of depth adjacency for determining perceived object characteristics.

However, it may be also possible to explain it in terms of the flow diagram of binocular vision (Julesz, 1971). It has been pointed out that binocular depth processing occurs before form recognition. Therefore, the illusory interaction between the rectangle and the oblique line may be expected to reduce, if they are first separated from each other and then received pattern recognition independently.

Further experiments, especially comparisons with monocular viewing condition, are necessary to investigate this point.

References

Gogel, W.C. **1975** Depth adjacency and the Ponzo illusion. *Percept. Psychophys.*, **17**, 125–132.

Julesz, B. **1971** *Foundation of cyclopean perception.* Chicago: University of Chicago Press.

Maruyama, K. & Iwasaki, S. **1973** "Prospective perception" and the tunnel phenomenon. *Tohoku Psychol. Folia*, **32**, 134–146.

Weintraub, D.J. & Krantz, D.H. **1971** The Poggendorff illusion: Amputations, rotations, and other perturbations. *Percept. Psychophys.*, **10**, 257–264.

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