The role of contour and location mechanisms in the Mueller-Lyer illusion*

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Ss judged two Mueller-Lyer configurations composed of solid and broken contours. The results suggest that there are strong positive and weak negative illusions produced by location and contour mechanisms, respectively. The method of adjustment is not appropriate for broken contours because it introduces motion errors. Within-sets methods are once again shown to be superior to more traditional between-sets methods.

Held (1970) has suggested that human visual perception involves distinct contour and location mechanisms. Stimuli that are composed of solid contours presumably excite both sets of mechanisms; broken contours excite only location mechanisms.

In the following series of experiments, Ss were asked to judge the relative magnitudes of the Mueller-Lyer illusions produced by solid and broken contours. Our hypothesis was that location mechanisms produce a positive illusion and contour mechanisms simultaneously produce a weaker negative illusion. The configuration with broken contours should, therefore, show more positive illusion than the solid configuration.

EXPERIMENT I

The Ss were 45 males and 3 females from an introductory course in psychology. They were given course credit for their participation.

Each configuration consisted of a continuous line divided into two shafts at the center by 4.0-cm obliques rotated 45 deg to the right. The left and right shafts were bounded on the left and right, respectively, by similar obliques rotated 45 deg to the left. The right shafts were 23.0 cm long. The left shafts were adjustable by the E through a tongue-and-groove arrangement. The solid configuration was constructed of 0.16-cm Presstape on white bristol board. The broken configuration consisted of 0.16-cm dots located every 1.0 cm along the apparent contours of the figure.

The S sat with his head firmly against a headrest 1.0 m from the stimulus. The average illuminance of the stimuli was 10.0 fc. All viewing was binocular.

The illusion was measured by the method of adjustment. Each S made two judgments of the solid and two of the broken configurations, one each ascending and descending. The serial order of these conditions was counterbalanced across blocks of four Ss.

The magnitude of the illusion was determined by taking the difference between the lengths of the left and right shafts at the point of subjective equality. The mean illusions for the solid and broken configurations were 2.3 and 2.5 mm, respectively. A three-way analysis of variance with repeated measures on one factor (Winer, 1971) was computed over solid vs broken configuration, first trial ascending vs descending, and first trial solid vs broken configuration. The results indicated that there were no significant main or interaction effects (Table 1). Thus, the data suggest that the basic Mueller-Lyer illusion is produced by location mechanisms, but they do not indicate whether contour mechanisms also produce a negative illusion.

EXPERIMENT II

We have observed that illusions are sometimes enhanced by monocular rather than binocular viewing. Experiment II was therefore designed to determine whether this procedure might also affect the differences between the illusions produced by solid and broken contours.

The Ss were 32 males and 16 females from the same population described above. All conditions were identical to those of Experiment I, except that the Ss used their preferred eyes only.

The magnitudes of the illusions produced by the solid and broken configurations were 2.8 and 3.2 mm, respectively. Monocular viewing thus produced a greater amount of illusion in both the solid ($t = 2.23$, $df = 94$, $p < .05$) and the broken conditions ($t = 2.45$, $df = 94$, $p < .02$) than did binocular viewing. As indicated in Table 1, however, the solid-broken main effects were not significant. Surprisingly, the order in which the trials were run was significant. If the S began with an ascending trial, he reported more illusions than if he began with a descending trial.

After careful questioning of several Ss and observing the effect ourselves, we feel that these data are artifacts of the method of adjustment. Most of the effect occurs in the broken conditions, as indicated by the large interaction terms. As the left side of the broken configuration is adjusted, the dots move rapidly by the S and create a secondary illusion of accelerated motion. As a result, the S tends to stop the adjustment of the broken contour sooner than they do the solid contour. This appears in the data as more illusion for ascending and less for descending trials. The S also seems to adjust the subsequent stimuli to the same length as the first stimulus irrespective of its apparent length. In short, the method of adjustment produces a unique motion error when applied to broken lines, and multiple trials produce a strong bias towards consistency, which partially masks the greater illusion from the broken configuration. Experiment III was therefore designed to circumvent these problems by using the method of reproduction.

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Table 1
Analysis of Variance from Experiments I and II

Source	F Ratios Experiment I	II
Ascending First (A)	0.12	14.99†
Solid First (S)	0.00	1.71
Broken vs Solid (B)	0.92	2.89*
A by S	0.26	0.00
A by B	0.48	2.22
S by B	0.15	0.31
A by S by B	0.38	4.87**

†$p < .001$ **$p < .05$ *$p < .10$

EXPERIMENT III

The Ss were 19 males and 5 females from the same population described above. The same stimuli were used, but the lengths of both the left and right shafts were fixed at 23.0 cm. Each S had two trials, one with each of the two stimulus configurations. He was asked to draw a line which had the same length as the difference between the left and right shafts. The order of the two trials was balanced across pairs of Ss.

The mean illusions in the solid and broken conditions were 1.7 and 2.3 mm, respectively. A t test on the mean differences showed that the broken configuration produced significantly greater illusion ($t = 2.14$, $df = 23$, $p < .05$).

EXPERIMENT IV

Howard, Wagner, & Mills (1973) have shown that within-sets methods that present pairs of experimental stimuli to the S are superior in many respects to the traditional methods used to measure illusions. We therefore replicated Experiment III, using a version of the method of pair reproduction as a check on the validity of the above results.

The Ss were 13 males and 3 females from the same population described above. The stimuli were duplicates of the left and right halves of the previous stimuli, arranged one above the other on 56.0 x 76.0 cm white posterboard. The serial order of the pair of solid and broken configurations and the serial position of the shafts with outward and inward obliques were counterbalanced across blocks of four Ss. The Ss were instructed to note any difference in the lengths of the pairs of solid and broken stimuli, and then to draw a single line which reflected the difference between the differences.

The data may be analyzed by either pair reproduction or pair comparisons procedures. The interval scale values obtained from the former method show a mean difference between the illusions of 2.4 mm. A t test indicated that this difference was highly significant ($t = 4.74$, $df = 15$, $p < .001$). The ordinal pair-comparisons data (i.e., which illusion dominated the other) were not rich enough to be scaled by the usual procedures. They were thus treated as simple frequency data which were also significant ($\chi^2 = 5.06$, $df = 1$, $p < .025$). The interval values were also significantly greater than those found in Experiment III ($t = 3.02$, $df = 38$, $p < .01$).

DISCUSSION

The results of these experiments suggest that location mechanisms produce the positive Mueller-Lyer illusion and contour mechanisms simultaneously produce a weaker negative illusion. It would be interesting to know if the adaptation and reversal of the Mueller-Lyer illusion (Köhler & Fishback, 1950) result from adaptation of the positive, but not the negative, component.

Several authors have suggested that the contour and location mechanisms can be related to the retinocortical and retinotectal visual systems, respectively (i.e., Ingle et al, 1968). Further analysis of the physiological data may thus provide insights into the nature of the Mueller-Lyer illusion, and vice versa. For example, we note that the neurons in the striate cortex are driven predominantly by binocular input. Hence, the use of monocular stimulation should reduce their contributions to the illusion. The general illusion resulting from monocular viewing in Experiment II thus tends to confirm the major result that positive illusion is not produced in the retinocortical contour system.

Our results also indicate that the method of adjustment may lead to differential subjective impressions of motion, and suggest that multiple trials are not independent. The greater t values and lower probabilities of Type I errors in Experiment IV likewise reaffirm our previous observation that within-sets procedures are superior to other scaling methods.

Finally, we would like to note that the multiplicity of experiments showing several types of illusions make single mechanism models no longer tenable (cf. Howard, 1971; Howard, Evans, & McDonald, in press). Studies that are sensitive to only one component must therefore be replaced by procedures which isolate these components.

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