SHORT REPORT

AN EXPERIMENTAL EXAMINATION OF THE SATIATION THEORY AND EFFERENT READINESS THEORY ON DECREMENT OF THE MÜLLER-LYER ILLUSION

HIRAYATSU TANAKA¹

Department of Psychology, Tokyo Metropolitan University

15 Ss were assigned to 1 of 3 viewing conditions to examine the effects of steady fixation and eye movements on decrement of the Müller-Lyer illusion. In Condition 1, a large number of brief tachistoscopic exposures were given with regular intervals during the inspection period and the Ss were instructed to fixate the center of the figure. In Condition 2, the figure was reversed 180° from exposure to exposure. In Condition 3, the figure was exposed continuously and the Ss were free to move their eyes. The magnitudes of decrement in all Conditions were nearly the same. The results were discussed in relation to Köhler & Fishback's satiation theory and Festinger et al.'s efferent readiness theory and concluded to support neither of these theories.

Decrement of the Müller-Lyer illusion with prolonged inspection has been observed in a large number of experiments in the past seventy years, but very few theoretical explanations of this phenomenon have been proposed.

Köhler and Fishback (1950a) asserted that decrement of the Müller-Lyer illusion was the result of asymmetrical satiation in the visual cortex. Satiation develops more strongly inside the angles of arrowheads than outside and makes the arrowheads displace apparently toward outside. Steady fixation should maximize this effect of satiation and result in maximal decrement. In addition, they reported that distributed trials caused greater decrement than massed trials (Köhler & Fishback,

1950b).

On the other hand, Festinger, White, and Allyn (1968) explained that decrement of the Müller-Lyer illusion was brought about by recalibration of the efferent program for eye movements activated by the illusion figure. According to their theory, the outward arrowheads of the Müller-Lyer figure activate efferent readiness for the extraocular muscles which is appropriate for a distance longer than the physical length of the horizontal line inserted between the arrowheads, therefore, the line is seen as longer than it really is. Correspondingly, the inward arrowheads activate efferent readiness appropriate for a shorter distance. Saccades to regard the apexes of arrowheads are hardly successful at first. The saccades are usually too long in the perceptually longer part of the figure and too short in the perceptually shorter part. Small corrective flicks following a large saccade are required to achieve an exact foveal fixation of an apex. During prolonged inspection, and these changes in eye movements should be accompanied by decrement in the perceived illusion. As steady fixation gives no opportunities to modify the

¹ The author is deeply indebted to Professor Tadasu Oyama of Chiba University for his critical reading of the manuscript and valuable suggestions. The author also wishes to thank Professor Yohei Wada, who is now at Meisei University, for constant encouragement in conducting the experiment.

Requests for reprints should be sent to Hirayatsu Tanaka, Department of Psychology, Tokyo Metropolitan University, Yagumo, Meguro-ku, Tokyo 152, Japan.

fferent program, the illusion should not show any decrement.

Thus, if decrement of the illusion is explained by the satiation theory, the *Ss* in a fixating condition will be expected to show greater decrement of the illusion than in free viewing. On the other hand, if efferent readiness interpretation is correct, free eye movements should be necessary for decrement of the illusion.

In the present study, an attempt was made to compare the effect of fixation and eye movements on decrement of the illusion and to evaluate relatively the two conflicting interpretations of this phenomenon. For the purpose, the following three types of display presentation, which were expected to maximize or minimize decrement of the illusion from either theory, were chosen and used in the experiment.

Condition 1. The distributed brief exposure condition. A large number of brief exposures are given with regular intervals during the inspection period. In this condition, asymmetrical satiation is expected to develop most favorably, for so-called "obstacle" against satiation is hard to develop (Köhler & Fishback, 1950b). As no actual eye movements can occur during brief exposures, the *Ss* will be given no chance to modify efferent readiness.

Condition 2. The distributed brief reversal exposure. A large number of brief exposures are given during the inspection period, and the figure is reversed 180° after every exposure. In this condition, the development of asymmetrical satiation will be confused.

Condition 3. The massed continuous viewing condition. Efferent readiness will be modified progressively because the *Ss* are permitted to make actual eye movements in this condition. Even under this condition, a little development of asymmetrical satiation may occur.

For comparison among the three viewing conditions, the Müller-Lyer figures were presented in a tachistoscope. According to the satiation interpretation, the magnitude of decrement will be expected in the following order, (1) > (3) > (2). On the other hand, according to the efferent readiness interpretation, (3) > (1) ≥ (2) will be expected.

METHOD

Subjects. Fifteen undergraduate volunteers were randomly assigned to the three conditions, five for each condition. None had previous experience in experiments of geometrical illusions.

Stimulus materials. Müller-Lyer figures of the Brentano type (three arrowheads without the connecting horizontal line) were drawn in Indian ink on white cardboards. The width of all lines was 1 mm. The distance between the apexes of outward arrowheads was 50 mm and used as the standard. The intersect angle of all arrowheads was 60°. Each line constructing arrowheads was 20 mm to 60 mm in steps of 2 mm and used as the comparison. The visual angle of the standard subtended at the eye was about 3.5°.

Procedure. A three-field tachistoscope (T. K.K.) with 83 cm viewing distance was used to present all displays. The light source for each field was a pair of 4-watt fluorescent lamps. A fixation point was presented in Field 3. The apexes of the central arrowheads on the other fields were placed just at the same place with this fixation point.

In Condition 1, the *Ss* were given some preliminary training in which they were asked to judge the sizes of pairs of circles in the tachistoscope. At the beginning of the session, a PSE for the Müller-Lyer figure obtained by means of the method of limits with two ascending and descending series (pretest). A judgment was made after each 200 msec exposure of the figure. This pretest was followed by three 5 min inspection periods, separated by 1 min rest periods.

The *Ss* were instructed to fixate the fixation point and the apex of central arrowhead of the Müller-Lyer figure during both pretest measurement and each inspection period, and to shut their eyes during each rest period. Each inspection period was consisted of 250 successive presentations of the Müller-Lyer figure and the fixation point, the former was exposed for 200 msec in Field 1, and the latter for 1 sec in Field 3. The comparison part of the Müller-Lyer figure in inspection period

TABLE 1
The magnitudes of the Müller-Lyer
illusion (mm)

Condition	Pretest		Posttest	
	Mean	S.D.	Mean	S.D.
1	11.64	0.53	9.28	1.37
2	11.12	7.25	8.88	4.97
3	13.16	4.88	8.58	6.09

was adjusted at objectively equal distance as the standard part. Total exposure time of the Müller-Lyer figure was 50 sec. At the end of session a PSE was obtained again (posttest).

In Condition 2, each of inspection periods interpolated between the pretest and posttest consisted of successive presentations of the Müller-Lyer figure and the fixation point. In this condition, the Müller-Lyer figures in Fields 1 and 2 were reversed 180° in orientation with each other and presented alternatively. Other procedure was the same as in Condition 1.

In Condition 3, a PSE was obtained at first with the method of limits in which each figure was exposed for 1 sec and two ascending series and two descending series were used (pretest). The Ss were free to move their eyes during judgments. This is followed by three inspection periods, separated by two 10 sec rest periods. The Ss were instructed to inspect the figure by looking back and forth along it in each inspection period, and to shut their eyes during each rest period. The length of each inspection period, 50 sec, was the same as the total exposure time of the Müller-Lyer figure at each inspection period in Conditions 1 and 2. Another PSE was obtained at last again (posttest).

Eye movements in the horizontal plane were monitored throughout the experiment by recording EOG with a multipurpose poligraph (Nihon Kohden RM-150).

RESULTS AND DISCUSSION

The mean magnitude of the illusion and standard deviations in the pretest and posttest for the three conditions are shown in Table 1.

The three conditions did not differ significantly in the initial magnitude of the illusion (pretest; $F=0.39$, $df=2,12$). In the posttest following the inspection periods, the three conditions showed significant decrement of the illusion ($t=4.86$, $p<.05$ for Condition 1; $t=2.30$, $p<.05$ for Condition 2; $t=3.26$, $p<.05$ for Condition 3; $df=4$). The percent change in the magnitude of the illusion was calculated. The mean decrement was 20.3%, 20.1% and 34.8% for Conditions 1, 2 and 3, respectively. But there was no significant difference among the three conditions ($F=1.28$, $df=2,12$).

The initial magnitude of the illusion corresponded to 20% of the standard distance both for the two presentation durations, 200 msec (Condition 1 and 2) and 1 sec (Condition 3). The former duration is much more than but the latter duration is equal to or shorter than a saccadic eye movement latency. This finding is consistent with the results of Lewis (1908), Bolles (1969) and Tanaka (1974). Particularly, Bolles and Tanaka suggested that even when the stimulus exposure is reduced to 50 msec the Müller-Lyer illusion still exists. In these case, visual angle subtended to the eye by the figure was 5°–7°. It may be concluded that eye movement do not necessary for the illusion.

The magnitudes of decrement in all Conditions were nearly the same. This finding does not agree with Köhler & Fishback's theory. Moed (1959) showed that the occurrence of decrement was not eliminated even when the orientation of the Müller-Lyer figure was reversed 180° in the same place after each trial. But the duration of each trial was longer than that in the present experiment (7.5 sec–60 sec in his study). Some other investigators have criticized Köhler & Fishback's theory on the basis of experimental results. Azuma (1952), Eysenck and Slater (1958), Pollack and Chaplin (1964) and Festinger et al. (1968) found that no decrement of the illusion when the Ss fixated the center of the figure during the inspection. Day (1962) showed that decrement of the illusion did not occur for the fixation of a large figure (20.6°) but occurred for the fixation of a small figure (6.3°). But,

Selkin and Wertheimer (1957) and Mountjoy (1960) found no significant difference between the fixation and free observation in decrement of the illusion; and Takino (1951), Morinaga (1969) and Moed (1959) reported that decrements occurred even when the Ss fixated figures. These reports were not consistent with the efferent readiness theory which predicts that actual eye movements are necessary for decrement of the illusion. All of the above-mentioned experimental results including the present experiment suggest that the development of asymmetrical satiation should not be a necessary condition for decrement of the illusion.

Our results do not support the Festinger et al.'s hypothesis, either. The comment of McLaughlin, DeSisto, and Kelly (1969) suggested that such eye movements are the result of, rather than the cause of the illusion, on the basis of the results of their eye movement experiments. Virsu (1971) suggested that inaccurate saccades for the Müller-Lyer figure could be accounted in terms of tendency to fixate the center of gravity of the arrowheads. Tanaka (1975) found that decrement occurred whenever the Ss fixated the center of the figure during judgments of the illusion in the situation of Festinger et al.'s type of fixating condition, whereas they allowed free eye movements and found no decrement. But, there was no decrement for the fixating condition of a large figure (24.0°) only when adjustments started always from the condition that the comparison (the stimulus part with inward arrowhead) was obviously longer than the standard, as in the experiment of Eysenck and Slater who found no decrement of the illusion.

Thus, the experimental results of the present study do not support either of the two theories. The results suggested that decrement of the illusion simply increased with the total time of exposures, regardless of presentation and observation conditions. This conclusion is in the same line with that of Parker and Newbigging (1963) who gave the Ss warm-up trials with a dumb-bell figure and showed that this training speeded up decrement of the Müller-Lyer illusion. The present results as well as Parker

and Newbigging's were not discordant with a theoretical formulation of differentiation mechanism offered by Gibson (1969). According to differentiation hypothesis, decrement of the Müller-Lyer illusion may be due to a process of learning to differentiate the main line from the accessory lines and to base the perceptual judgment mostly upon the main line. This differentiation mechanism should be independent of the differences in the presentation and observation condition induced in the present study.

REFERENCES

- AZUMA, H. 1952 The effect of experience on the amount of the Müller-Lyer illusion. *The Japanese Journal of Psychology*, **22**, 111-123. (In Japanese with English summary)
- BOLLES, R. C. 1969 The role of eye movements in the Müller-Lyer illusion. *Perception & Psychophysics*, **6**, 175-176.
- DAY, R. H. 1962 The effects of repeated trials and prolonged fixation on error in the Müller-Lyer figure. *Psychological Monograph*, **76**, No. 14 (Whole No. 533)
- EYSENCK, H. J., & SLATER, P. 1958 Effects of practice and rest on fluctuations in the Müller-Lyer illusion. *British Journal of Psychology*, **49**, 246-256.
- FESTINGER, L., WHITE, C. W., & ALLYN, M. R. 1968 Eye movements and decrement in the Müller-Lyer illusion. *Perception & Psychophysics*, **3**, 376-382.
- GIBSON, ELEANOR J. 1969 *Principles of perceptual learning and development*. New York: Appleton-Century-Crofts.
- KÖHLER, W., & FISHBACK, JURIA 1950a The destruction of the Müller-Lyer illusion in repeated trials: I. An examination of two theories. *Journal of Experimental Psychology*, **40**, 267-281.
- KÖHLER, W., & FISHBACK, JURIA 1950b The destruction of the Müller-Lyer illusion in repeated trials: II. Satiation patterns and memory traces. *Journal of Experimental Psychology*, **40**, 398-410.
- LEWIS, E. O. 1908 The effect of practice on the perception of the Müller-Lyer illusion. *British Journal of psychology*, **2**, 294-306.
- McLAUGHLIN, S. C., DESISTO, M. J., & KELLEY, M. J. JR. 1969 Comment on "Eye move-

- ments and decrement in the Müller-Lyer illusion". *Perception & Psychophysics*, **5**, 288.
- MOED, G. 1959 Satiation theory and the Müller-Lyer illusion. *American Journal of Psychology*, **72**, 609-611.
- MORINAGA, S. 1969 *The psychology of perception*. Tokyo: Meigen Shobo, 370-374. (in Japanese)
- MOUNTJOY, P. T. 1960 Fixation and decrement to the Müller-Lyer figure. *Psychological Record*, **10**, 219-223.
- PARKER, NORA I., & NEWBIGGLING, P. L. 1963 Magnitude and decrement of the Müller-Lyer illusion as a function of pre-training. *Canadian Journal of Psychology*, **17**, 134-140.
- POLLACK, R. H., & CHAPLIN, MARY R. 1964 Effects of prolonged stimulation by components of the Müller-Lyer figure upon the magnitude of the illusion. *Perceptual & Motor Skills*, **18**, 377-382.
- SELKIN, J., & WERTHEIMER, M. 1957 Disappearance of the Müller-Lyer illusion under prolonged inspection. *Perceptual & Motor Skills*, **7**, 265-266.
- TAKINO, C. 1951 On Köhler's satiation theory. *The Japanese Journal of Psychology*, **21** (No. 3-4), 97. (in Japanese)
- TANAKA, H. 1974 The effect of exposure time in magnitudes of some geometrical illusions. *Proceedings of the 38th Annual Meeting of Japanese Psychological Association*, 208-209. (in Japanese)
- TANAKA, H. 1975 The role of eye movements in decrement of some geometrical illusions under prolonged inspection. *The Journal of Social Sciences & Humanities* (Tokyo Metropolitan University), in press. (in Japanese with English summary)
- VIRSU, V. 1971 Tendencies to eye movement, and misperception of curvature, direction, and length. *Perception & Psychophysics*, **9**, 65-72.

(Received May 15, 1975)