Decrement of the Müller-Lyer illusion with saccadic and tracking eye movements[1]

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Subjects viewed the Müller-Lyer illusion, making either saccadic or smooth tracking eye movements between the apexes of the arrowheads. The decrement in the magnitude of the illusion was significantly greater for Ss in the saccadic viewing condition. Saccadic and smooth tracking eye movements are separately controlled, and information about eye position is more readily available from the efferent signals issued to control a saccadic eye movement. The experimental findings were consistent with the hypothesis that Ss in the saccadic condition learned a new afferent-efferent association. The results support a theory that visual perception is determined by efferent readiness activated by visual afferent stimulation.

One current theoretical account of visual perception proposes that the conscious experience of perception is determined by the efferent readiness activated by visual afferent stimulation (Festinger, Burnham, Ono, & Bamber, 1967). This theory states that what one sees is at least in part determined by how one is prepared to respond. Initial empirical tests of this efferent readiness theory involved studies showing that adaptation to prismatically induced curvature occurs only when a person is required by the experimental situation to learn a new efferent response to the visual input (Festinger et al, 1967).

There are perceptual situations other than adaptation to prismatically induced curvature wherein a change in visual perception can be attributed to the learning of new afferent-efferent associations. One such situation is the viewing over time of geometrical visual illusions. It has long been known that such illusions decrease with continued viewing (e.g., Judd, 1902). The decrement in an illusion such as the Müller-Lyer can readily be explained by a recalibration of the efferent program for eye movements activated by the illusion figure. When the illusion is first viewed, the outward pointing lines may result in the activation of a response readiness for the extraocular muscles appropriate for a distance longer than the connecting line; the line is therefore seen as longer than it actually is. Correspondingly, the inward pointing lines activate efferent readiness appropriate for a shorter connecting line. If this interpretation were correct, eye movements to fixate the apexes would not be successful when the illusion was first viewed. The saccadic eye movements would be too long on the perceptually long side of the illusion and too short on the perceptually short side. Small corrective flicks following a large saccade would be expected to achieve foveal fixation of the apexes. With continued viewing the incorrect large saccades and the corrections should decrease, and this change in eye movements should be accompanied by a decrement in the perceived illusion. Festinger, White, and Allyn (1968) report eye movement and illusion decrement data supporting this interpretation. The Ss in a Scan condition showed both a greater decrement in the illusion and a greater alteration of eye movements in the predicted direction than did Ss in a Fixate condition.

This interpretation and these data conflict with reports of decrement in the Müller-Lyer illusion with fixated viewing, a result interpreted as supporting a cortical satiation hypothesis of the decrement (Köhler & Fishback, 1950). Other investigators, including Eysenck and Slater (1958) and Pollack and Chaplin (1964), have failed to find a decrement with fixated viewing. Festinger et al (1968) suggest that the decrement with fixated viewing may be due to the use of an illusion figure subtending a small visual angle wherein imperfect fixation, which might be expected to occur during measurements, could result in a recalibration of afferent-efferent associations. They found a similar and significant decrement in settings of the Müller-Lyer illusion made with eye movements for Ss who fixated the illusion figure and for Ss who scanned a neutral figure during inspection trials.

In sum, there is considerable support for the hypothesis that eye movements are a major factor in the decrement of the Müller-Lyer illusion. However, recent physiological and psychological data suggest that if the efferent readiness interpretation of the decrement is correct then there should be little or no decrement following viewing while making smooth tracking eye movements. Saccadic and tracking eye movements are responses to different aspects of visual stimulation and are controlled by different mechanisms in the central nervous system. Rashbass (1961) demonstrated that tracking eye movements are a response to the direction and velocity of moving objects whereas the saccadic movement is a fixation response to position. He also found that barbiturates disrupt smooth tracking but not saccadic eye movements. Brindley and Merton (1960) demonstrated the importance of efference by showing that information about eye movements resulting from the proprioceptive inflow from the extraocular muscles is not available to consciousness. And Festinger and Cannon (1965) found that the localization of an object in space is more accurate when saccadic rather than tracking eye movements provide positional information. The implication of these differences for adaptation to the curvature produced by wearing a prism on a scleral contact lens has been tested by Festinger et al (1967) and Slotnick (1966). Adaptation was consistently greater when Ss viewed a contour while scanning with saccadic eye movements than while tracking with smooth eye movements.

Only with saccadic eye movements is there an opportunity for the learning of new afferent-efferent associations and thereby a change in perception. The hypothesis of the present investigation is that there will be more decrement in the Müller-Lyer illusion following saccadic viewing than viewing while making smooth tracking eye movements. Confirmation of this hypothesis would further support the efference interpretation of the illusion decrement because it is possible to more nearly equate the visual input and the proprioceptive inflow from the extraocular muscles in saccadic and tracking conditions than in saccadic and fixation conditions.

METHOD

Apparatus and Procedure

The Brentano version of the Müller-Lyer illusion without a connecting horizontal line was used. The study was conducted in a light-proof room, and the arrowheads were formed of luminous paint. The two angled lines of each arrowhead were 1/4 in. wide and 1-3/4 in. long and formed an angle of 30° with the horizontal. The standard portion of the illusion, located on the left and consisting of the inward pointing lines, was 6-7/8 in. from apex to apex. The comparison arrowhead was adjusted by turning a knob, and the distance between the middle and right apexes could vary from 2-1/2 to 11 in.

Two such illusion figures were constructed, one for the saccadic eye movement condition and the other for the smooth tracking condition. The apparatus for the Saccadic condition had a light bulb placed at each of the three apexes. The apparatus for the Tracking condition had a single movable bulb attached to a track behind the apparatus. This bulb was moved from apex to apex by a motor and pulley arrangement and was visible throughout its path.

The S viewed the illusion with his right eye; the center apex was located 24-1/2 in. in front of this eye. The standard part of the illusion subtended a visual angle of 15.7°. Head movements were prevented by a bite board and padded chin and forehead supports.

An experimental session consisted of two initial settings to a point of subjective equality (PSE) and two viewing periods of approximately 75 sec, each followed by settings. For the settings E first moved the comparison portion of the figure to a short position and S was instructed to adjust it so that the distances between the apexes looked equal. Then S shut his eyes while E read the position of the setting with the aid of a flashlight and moved the comparison portion to a long position from which S made a second setting. The S rested with his eyes shut for a 30-sec interval after this second setting while E read the setting and placed the comparison figure at S's PSE. The figure was placed at S's initial PSE for both viewing periods. The only visual stimulation during the settings was from the luminous arrowheads; the light bulbs were on only during the viewing periods.

The sequence of lights in the Saccadic condition was designed to enable S to learn a new afferent-efferent association. The bulbs at the apexes were lit in the following order: left, middle, right, middle, left, etc. Each bulb was on for 1 sec; the following bulb came on after the preceding bulb had been off for 1/2 sec. S was told to fixate the lit bulb and, when it went off, to look at the apex at which the next bulb would come on. Each viewing trial lasted 73 sec and consisted of 12 left-to-right-to-left sequences.

The single light in the Tracking condition started at the left apex, moved to the middle and then to the right apex, and continued moving back and forth in this manner for 12 round trips. It stopped at each of the three apexes for 1/2 sec. The S was told to fixate the light at all times and to follow it back and forth with his eyes. The viewing trials in this condition averaged 75 sec. Since the motor pulled the bulb at a constant speed, the tracking trials varied slightly in time depending on S's PSE.

Pretesting of this experimental condition showed that the clicking of the relays operating the delay and reversing circuitry for the motor driven bulb provided a highly salient clue to the relative distances between the apexes. With the figure at PSE, the time interval from the left to the middle apex was obviously longer than the time interval from the middle to the right apex. Many Ss thus realized that the distances were unequal and compensated for this in their post-viewing period settings by adjusting the arrowheads to a distance which they judged to be equal but which they later stated did not look equal. Consequently a white noise tape loop on which clicks were superimposed at random intervals was used to mask the apparatus noise. Although unnecessary, the same loop was played for Ss in the Saccadic condition.

Subjects

Subjects were 25 students fulfilling a portion of an introductory psychology course requirement. The data from one S, who had been assigned to the Tracking condition, were not included in the analysis. The initial illusion magnitude of this S was atypically low, being only 6.3% of the standard. He stated after the experiment that he always attempted to set the distances between the arrowheads so that they would be equal rather than look equal. He was also the only S whose PSE following a viewing period was greater than objective equality. With this S excluded, there were 12 Ss in each condition.

RESULTS

The two groups did not differ significantly in the initial magnitude of the illusion ($t = 0.99$, $df = 22$). The mean initial illusion for Ss in the Saccadic condition was 2.03 in. or 29.5% of the standard. For Ss in the Tracking condition the comparable data were 1.83 in. or 26.6%.

The percentage change in the magnitude of the illusion was calculated for each viewing period and analyzed by a 2 by 2 analysis of variance, with conditions and trials as the variables. There was a significant difference between the two viewing conditions ($F = 16.71$, $df = 1/22$, $p < 0.001$). The mean percentage decrement in the Saccadic condition was 36.7%; in the Tracking condition it was 11.3%. The mean percentage change after the first trial was 20.4%; after the second trial it was 27.6%. The trial effect was not significant ($F = 2.07$, $df = 1/22$, $p > 0.05$). The interaction between conditions and trials did not approach significance ($F < 1.00$).

A simple t test was performed on the percentage decrements after the second viewing period for each condition to see if the decrement at this time was significantly different from zero. The mean decrement of 13.8% for Ss in the Tracking condition was not significant ($t = 1.82$, $df = 11$, $p < 0.10$). The mean decrement of 41.4% for Ss in the Saccadic condition was highly significant ($t = 6.94$, $df = 11$, $p < 0.001$).

DISCUSSION

It is clear that saccadic viewing caused a considerably larger decrement in the magnitude of the Müller-Lyer illusion than smooth tracking viewing. Perhaps most of the decrement in the Tracking condition, as well as a portion of the decrement in the Saccadic condition, can be attributed to learning resulting from the psychophysical procedure used to make the adjustments to apparent equality. Parker and Newbigging (1965) found that when Ss made adjustments using a procedure which intermixed longer and shorter settings of the variable portion of the figure there was a fairly rapid decrease in the magnitude of the illusion. The adjustments in the present investigation were made with a similar procedure.

A common explanation of the decrement in the magnitude of the Müller-Lyer illusion with continued viewing refers to "perceptual learning" (e. g., Woodworth & Schlosberg, 1954; Parker & Newbigging, 1965). The results from this study support this explanation but specify in terms of a general theory of perception what is learned, namely a new afferent-efferent association. The obtained pattern of results for the saccadic and tracking viewing conditions cannot easily be accounted for by other current explanations of the decrement in the illusion. Presumably the habituation effect (Mountjoy, 1958) would be similar for both conditions, since this is hypothesized to vary solely with the number of trials and intertrial interval. As much satiation (Köhler & Fishback, 1950) would probably be expected to occur in the two conditions of this study. Explanations of the illusion based on inappropriate constancy scaling (Gregory, 1963) or perceptual inference habits due to the viewer's ecological environment (Segall, Campbell, & Herskovits, 1966), although perhaps appropriate as a partial explanation of the cause of the illusion, would also appear to predict no difference in decrement as a result of saccadic as opposed to tracking viewing. The obtained results agree with those reported by Festinger et al (1968). Both studies support the efferent readiness theory of perception and extend that theory from the perception of contour to the perception of length.

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Note

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