EXPERIMENTAL NOTE ON FADING OF BRIEFLY FLASHED LINES

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Summary.— A peripheral uniform stimulus on a uniform background tends to fade when a ring enclosing the stimulus is flashed briefly, indicating that neural signals external to the stimulus such as those from the ring or those from the background tend to inhibit the onset-response or after-discharge of the stimulus. In this study, a peripheral achromatic line was flashed briefly on an achromatic background while the subject was steadily fixating on a point on the background. It was predicted that the stimulus line would fade due to background inhibition of the onset-response or after-discharge of the stimulus. On a reference line, subjects indicated two points delimiting the part of the stimulus line which looked uniform in intensity of color. These points converged toward the center of the reference line as the luminance of the stimulus line approached that of the background. Compared to the central uniform part, the nonuniform parts near the endpoints of the stimulus line looked more faded. These results support the idea that the background surrounding a stimulus tends to inhibit the onset-response of after-discharge of the stimulus.

A visual stimulus flashed briefly produces an initial neural signal called onset-response and a terminal neural signal called after-discharge, each affecting the visibility of the stimulus as indicated by the suppression of the onset-response by forward masking and of the after-discharge by backward masking (Macknik & Livingstone, 1998; Macknik, Martinez-Conde, & Haglund, 2000). When one steadily fixates on a point on a uniform background on which there is a peripheral stationary stimulus, the stimulus tends to fade when a ring enclosing the stimulus is flashed briefly, indicating that neural signals external to the stimulus produced by the ring tend to inhibit the onset-response or after-discharge of the stimulus (Kanai & Kamitani, 2003). Consider a line flashed briefly on a uniform background while the subject steadily fixates on a point on the background. Spatially, this background is assimilable to the ring in Kanai and Kamitani’s study since both enclose a stimulus. Thus, one may suppose that neural signals external to the line produced by the background tend to inhibit the onset-response or after-discharge of the line. This inhibition would be stronger along the longer axis of the line since the immediate area of the background enclosing the endpoints of the line is more extended than the immediate area of the background near the other points of the line. Thus, one may predict that the onset-response or after-discharge of the line are inhibited more near the endpoints of the line. The finding that a stabilized retinal image fades increasingly more as the luminance difference between the image and the background decreases (Sharpe, 1972; Olson, Tulunay-Keesey, & Saleh, 1993) indicates that the background more easily inhibits the onset-response or after-discharge when these signals are weak. A line flashed briefly is retinally stabilized when a subject is steadily fixating on a point on the background. Thus, one may predict that such a line tends to fade near its endpoints increasingly more as the luminance difference between the line and the background decreases. The following experiment was designed to test this possibility.

Method

Subjects
Twelve undergraduate university students were recruited as they entered the department to participate as subjects in the experiment. All of them had normal or corrected-to-normal vision and ignored the purpose of the experiment.
Stimuli

The stimuli appeared in the middle of a 32 × 21 cm rectangular achromatic area of the frontal parallel screen of a display (Apple Multiple Scan 1705) driven by a computer (Power Macintosh 7200/90). The remaining area of the screen was covered with black cardboard. The luminance of the screen was 10 cd/m$^2$ with illumination level of 2 lx. The viewing distance was maintained at 62 cm by a head-and-chin rest.

A black fixation cross with arms measuring 0.3 × 1 mm was constantly displayed in the middle of the screen. The stimulus was one 0.3 × 50 mm achromatic vertical line presented for 50 msec either on the left or on the right of the fixation cross. The luminance of the stimulus line was 0.5, 5, or 8 cd/m$^2$. The centers of the stimulus line and of the fixation cross were horizontally aligned, with a gap between the two of 38 mm (3.5º). Below the fixation cross, a 0.3 × 50 mm vertical black line was constantly displayed. This line was used as a reference line. The center of the reference line and that of the fixation cross were vertically aligned, with a gap of 50 mm between the cross and the top endpoint of the reference line.

Procedure

Subjects were asked to focus on the fixation cross when the word “ready” was pronounced by the experimenter. They were asked to indicate on the reference line, after the stimulus line has disappeared, two points delimiting approximately the part of the stimulus line that looked uniform in intensity of color. Subjects were asked to indicate these points on the reference line by positioning the center of a white cross with arms of 0.3 × 2 mm on each point. They first positioned the cross on one point and clicked on the mouse, and then positioned the cross on the other point and clicked on the mouse again. The computer recorded the positions of these points on the reference line when the subject clicked on the mouse.

The two locations and the three luminances for the stimulus line produced six different stimuli. The series of these six stimuli was presented five times consecutively, each time with stimuli in random order. Responses to stimuli in the first series were discarded.

RESULTS

In Fig. 1, the vertical axis represents the reference line with “0” and “50” representing the bottom and top endpoints of this line, respectively. The mean point indicated by the subjects on the reference line, averaged over the two positions and the four repetitions of the stimulus line, is represented on the vertical axis as a function of the luminance of the stimulus line. Error bars indicate one standard error above or below the mean when this error was larger than a dot symbol. The arrow indicates the luminance of the background (Bkg).

Thus, it turned out that the uniform part of the stimulus line was an internal part of the line which included the center of the line. Mean points converged toward the center of the reference line as the luminance of the stimulus line approached that of the background. For the mean points near the bottom and for those near the top of the reference line, this convergence was significant ($F_{2, 22} = 5.6$ and $F_{2, 22} = 6.5, p < 0.01$, respectively) and was essentially independent of the left-right position of the stimulus line ($F_{1, 11} = 3.6$ and $F_{1, 11} = 1.4$, respectively). Inspection of individual data showed that, essentially, each subject produced a pattern of results as that shown in Fig. 1. It may be seen that the effects were large. For example, the mean length of the part of the stimulus line with uniform color was about 30% shorter than the full length of this line when the luminance of this line was 8 cd/m$^2$.

When the subjects were asked, they reported that the nonuniform parts near the endpoints of the stimulus line looked more faded than the central uniform part of this line. The extent of the faded nonuniform parts near the endpoints of the stimulus line increased as the luminance difference between this line and the background decreased. These results support the idea that the background surrounding a briefly flashed stimulus tends to inhibit the onset-
response or after-discharge of the stimulus. The small standard errors of the means relative to the lines with luminance of 0.5 cd/m² shows that the larger standard error of the means relative to the other lines was largely due to the variability of the perceived length of the faded parts of the lines rather than to response bias. This perceptual variability indicates a large random component in the inhibition of the onset-response or after-discharge.

REFERENCES

FIG. 1. The vertical axis represents a 50-mm long reference line with “0” and “50” representing the bottom and top endpoints of this line, respectively. A briefly flashed 50-mm long stimulus line was varied in luminance on a background with the luminance indicated by the arrow (Bkg). On the reference line, subjects indicated the two points of the stimulus line that delimited the part of the stimulus line that looked uniform in intensity of color. The resulting mean points in mm are represented on the vertical axis as a function of the luminance in cd/m² of the stimulus line. Error bars show one standard error above or below the mean.