Visual-evoked response produced by patterned light stimulus

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The photopic visual-evoked response (VER) produced by patterned stimuli was examined by changing: (1) the stimulus magnitude, (2) the contour density of the test pattern, and (3) the contour contrast. In the majority of normal subjects the VERs obtained by a grating pattern showed their maximum response at a relatively low level of stimulus magnitude. With a logarithmic increase in contour density of the test pattern, the response amplitude increased in almost linear fashion. The VERs to the multiple-hole pattern of different contrast showed an S-shaped increase of the amplitude with an increase of log contrast. The latency of these VERs showed very small change when contour density or contrast was changed. The results suggested that there were two different components in the VER. The one was due to the light sensitivity and the other was due to the contrast sensitivity in the visual system. The latter seemed to be dominant in the photopic VER.

Key words: visual-evoked response, patterned luminous stimulus, contour density, contrast

Studies of visual-evoked responses (VER) produced by patterned stimuli have shown several interesting features. The response has a characteristic biphasic wave which seems to be different from those waves observed in the response to an ordinary simple luminous stimulus. The amplitude of the wave is closely related to the amount of edge in the test pattern (contour density or interface density). Through the artificial blurring of contour, the response pattern can be converted to one which is identical to those obtained by a simple luminous stimulus. The patterned stimulus produces larger responses than those obtained by a simple luminous stimulus of the same intensity level. These findings suggest that the examination of the VER produced by patterned stimuli might have a different significance for the study of visual function than that produced by a conventional unstructured light source.

The present experiments were designed to obtain more information about the VER produced by patterned stimuli in respect to the stimulus magnitude, contour density, and contrast of the test pattern.
Methods

Five male and nine female subjects were selected among the volunteers who had participated in another VER study because of their definite response and its consistency. They were all hospital or university employees of good health; their ages ranged from 21 to 40 and visual acuity (with correction if necessary) was 20/20 or better. No mydriatic subjects were used since it had been reported that the pupil size of normal subjects had little effect on the VER.1

The subjects were seated on chairs in front of a hemisphere in an electrically shielded room. The diameter of the hemisphere was 152 cm., and the inside was painted matte white. At the center of the hemisphere there was a hole of 14 cm. diameter through which photic stimuli were delivered. The background luminance was set at approximately 60 apostilbs for light adaptation. Throughout the experiment, only binocular stimulation was employed, and no consideration was given to the effect of binocular fusion.

Five grating patterns of different element size (size of the transparent square) ranging from 9 to 93 minutes of arc of visual angle were used in the study of contour density (Fig. 1). They were made from a transparent plastic plate, 14 cm. diameter, on which black line conductor tape of different widths was attached with a blank space of the same width to form a grating pattern. Thus the amount of stimulus light coming through each pattern was the same (equal to one quarter of the light coming through blank stimulus pattern).

In the contrast study, multiple-hole patterns made of neutral density filters of different transmissions (Kodak No. 96) were used (Fig. 2). They were mounted on 35 mm. slide frame (35 mm. horizontal and 23 mm. vertical of picture size or 2° 34' x 1° 41' of arc of visual angle) and had 35 holes of 3 mm. diameter (13' of visual angle). Thus each pattern had the same amount of contour density but different amount of contrast. The making of these regular holes on easily crackable gelatin filters was accomplished by using a flat-head drill (Dremal Drill No. 113) which was attached to a stereotaxic electrode holder (Narishige SM-15). Eleven patterns of different contrast ranging from log contrast 0.10 to 2.00 and a blank pattern were used.

Both grating and contrast patterns were placed at the center of the hemisphere at a distance of 76 cm. from the eye. No particular fixation point was shown on the test pattern. The subject was merely asked to keep his gaze at the center of the pattern.

A xenon lamp was used as the stimulus source (Grass PS2) and was placed 8 cm. behind the hemisphere. A milky white plastic plate (63 per cent light transmission) was placed in front of the lamp reflector to obtain a homogeneous light flash. The click sound of the xenon discharge was masked by white noise. The subjective threshold level of stimulus magnitude in each subject was determined by means of neutral density filters (Kodak No. 96, N.D. 1.00) and by using the magnitude scale of the stimulator. In all 11 subjects threshold levels for both the grating pattern No. 60 and the multiple-hole pattern of log 2.00 contrast were found to be 4 log units below Is. Is on the stimulator scale was approximately equal to 750,000 candlepower with a duration of approximately 10 μsec according to the manufacturer's specifications. The stimulus flash was delivered at the frequency of 1.6 Hertz units (Hz) and was triggered by a square-wave generator (Grass S8).

The VERs were picked up through a pair of electrodes which were placed on the inion.
Fig. 2. Eleven multiple-hole patterns of different contrast as well as the blank stimulus used. Contrast levels are, from high to low, log 2.00, 1.00 to 0.10 in 0.10 steps, and a blank stimulus, and at 6 cm. above the inion. The ground connection was made on the left earlobe. Both monopolar and bipolar leadings were employed, and the responses were recorded on magnetic tape after conventional amplification. Sixty-four responses were averaged using a computer (Fabritek 5012) after 25 Hz low-pass filtering, and the final traces were obtained by an X-Y recorder. A delay of the response caused by the electronic filtering was taken into consideration. The measurements presented in this paper were all taken from bipolar recordings because of the better signal-to-noise ratio. The amplitude of the patterned-stimulus response was measured from peak to peak of the biphasic wave (positive-negative wave complex) which had an implicit time at approximately 80 to 100 msec. for the positive peak and 140 to 180 msec. for the negative peak in its maximum response. The amplitude of the plain-stimulus response was measured from peak to peak of the maximum wave with the implicit time between 100 and 300 msec. The latency of the patterned-stimulus response was measured from stimulus to both positive and negative peaks of the biphasic wave. The latency of the plain-stimulus response was measured from stimulus to the negative peak of the maximum wave.

Results

Effect of stimulus intensity (Figs. 3, 4, and 5). Eleven subjects were examined with the finest grating pattern (No. 60 or 9' of visual angle per element) at five different levels of stimulus intensity ranging from 0 to 4 log units above threshold. In 7 subjects the maximum amplitude of the response was observed at the
Fig. 3. Visual-evoked responses (Subject M. B.) produced by the grating pattern (No. 60) and by the plain light stimulus with five different levels of stimulus magnitude. Each trace shows the averaged result of 64 responses. The dotted line indicates the stimulus flash. Vertical bipolar recording. Negativity upward.

Fig. 4. Relative amplitude of the visual-evoked responses obtained by the grating pattern (No. 60) and by the plain light stimulus plotted against log stimulus magnitude. The responses are averages of eleven subjects. One standard deviation is indicated. The maximum amplitude in each individual was set as 100 per cent.

Fig. 5. Latency of the visual-evoked responses obtained by the grating pattern (No. 60) and by the plain light stimulus plotted against log stimulus magnitude. Average of eleven subjects as in Fig. 4.
stimulus magnitude level of 2 or 3 log units, and the amplitude began to decrease when the stimulus intensity was increased to the level of 4 log units above threshold. In comparison, the VERs obtained with unstructured light stimulus were much smaller and showed a steady increase of the amplitude (peak to peak of maximum wave) with the increase of stimulus magnitude. Usually, the difference in the amplitude between the patterned-stimulus response and the plain-stimulus response was most marked with the stimulus magnitude of 2 log units above threshold. At the stimulus magnitude level of 2 or 3 log units above threshold the patterned-stimulus response had the shortest latency. In 8 subjects the latency showed a prolongation when the stimulus magnitude was increased to more than 3 log units. In two subjects the response showed both an increasing amplitude and a decreasing latency with the increase of stimulus magnitude through the 4 log unit range.

In subjective perception, the contour of the grating pattern could be seen most clearly at a magnitude level of 2 and 3 log units above threshold. At the highest magnitude (4 log units above threshold) most subjects felt a moderate amount of glare with blurring of the contour and a scattering of the light into the peripheral visual field.

The stimulus magnitude in the subsequent experiments was set at a level of 2 log units above threshold in view of the previous findings.

**Effect of contour density (Figs. 6 and 7).** Six subjects were examined with 5 grating patterns of different contour density as well as a blank stimulus. Four subjects showed both quantitative (amplitude change) and qualitative (gradual
Fig. 7. Relative amplitude of the positive-negative wave complex in visual-evoked response obtained by grating patterns of different contour density. The number in contour density indicates relative amount of edge of the test pattern. The stimulus magnitude was 2 log units above threshold. Average of six subjects. The maximum amplitude in each individual was set as 100 per cent. One standard deviation is indicated.

Conversion of the response pattern changes (Fig. 6, Subject M. S.), and two subjects showed only quantitative changes (Fig. 6, Subject M. B.). In all subjects the latency showed very small change when the contour density was altered. In the averaged results, the amplitude of the characteristic biphasic wave (positive-negative wave) increased in almost linear fashion with logarithmic increase of contour density within the range between pattern No. 13 (46' of visual angle per element) and pattern No. 60 (9').

Effect of contour contrast (Figs. 8 and 9). Although there were moderate fluctuations of the response amplitude in the records of five subjects examined with multiple-hole patterns of different contrast, the amplitude increased forming an S-shaped curve with the logarithmic increase of contrast. The response amplitude reached a gradual saturation when the contrast was increased beyond the level of 0.5 log units. The latency showed only a small decrease with increasing contrast.

Discussion
Although there have been several papers dealing with the VER to the patterned stimuli, not much consideration was given to the effect of stimulus magnitude. The results in the present experiment showed that the maximum response at photopic adaptation levels appeared at relatively low level of stimulus magnitude. It was interesting that the subjective feeling of glare and blurring of contour which occurred at the higher level of stimulus magnitude was accompanied by a decrease of the response.

The early saturation phenomenon and the characteristic response pattern suggest that the VER to the patterned stimulus might be different in its nature from those
Fig. 8. Visual-evoked responses (Subject M. B.) produced by the multiple-hole patterns of different contrast. Each trace shows the averaged result of 64 responses. The dotted line indicates the stimulus flash. The stimulus magnitude was 2 log units above threshold. Vertical bipolar recording. Negativity upward.

Fig. 9. Relative amplitude of the positive-negative wave complex in visual-evoked response obtained by the multiple-hole patterns of different contrast. The stimulus magnitude was 2 log units above threshold. Average of five subjects. The maximum amplitude in each individual was set as 100 per cent. One standard deviation is indicated.
obtained using an unstructured stimulus. In some cases in the present experiment, almost no response was obtained when using the unstructured stimulus (e.g., Subject M. B. in Figs. 6 and 8). When the patterned stimulus was employed, a large response resulted despite the fact that the plain nonpatterned stimulus allowed more light to pass. It might well be, therefore, that the VER obtained by a patterned stimulus in these cases was caused by the contrast borders in the test pattern and was not significantly related to the luminous stimulus itself.

It has been reported recently that no particular reduction of the VER was found in the examination of the patients with functional amblyopia by using an unstructured light stimulus. However, it might be necessary to distinguish light sensitivity of the visual system from the contrast sensitivity when higher order neurons are examined. From animal experiments, it is known that most units in the cat's visual cortex do not respond to diffuse illumination and that spot illumination, contrast border, or a moving edge are more effective in evoking unit activity in the striate cortex of the cat and the monkey. These facts support the findings in human VER produced by patterned stimuli.

The effect of contrast observed in the present experiment was similar to that obtained in the study of the receptive fields in geniculate neurons of the cat. However, the results from measurements of subjective visual acuity with test charts of different contrast have shown only a small decrease of visual acuity at lower contrast ranges. This indicates the involvement of factors in subjective visual acuity other than those which participate in a simple neurophysiologic response.

The experimental results outlined and a consideration of the normal visual environment which is composed of many different contours and contrasts suggest that it might be more natural to employ patterned light stimuli of moderate luminance for studying the VER than to use unstructured light flashes of high luminance.

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REFERENCES