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EFFECTS OF STIMULUS CONTRAST ON BINOCULAR VER

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Summary: The effect of stimulus contrast changes on the binocular visual evoked response (VER) was investigated using pattern reversal VER, dichoptic stimulation, and Fast Fourier Transform. When the stimulus contrast was changed binocularly, the monocular components increased as the contrast increased. The binocular component first appeared at the level of 10% contrast; its magnitude was stable under all recording conditions. When the stimulus contrast was changed monocularly, the eye that received the higher contrast stimulation showed more power in the power spectrum. The binocular component appeared even when the difference in contrast between the two eyes was large. The magnitude of the binocular component was stable under all recording conditions. We concluded that the binocular and the monocular components differ in the magnitude of their responses to a contrast change and speculate that the pathways responsible for the two components are not identical.

Key Words: Binocular function, pattern reversal VER, Fast Fourier Transform, binocular component, contrast

Introduction

Several investigators[2,9,12] have used pattern reversal visual evoked response (VER) for evaluating binocular function. In one such method, using dioptic stimulation, the binocular function is evaluated by the amount of binocular summation. However, the degree of the binocular summation is greatly influenced by various stimulus parameters. In a newer method[1,2,4,5,11], using dichoptic stimulation, the binocular function is evaluated by the presence of interocular suppression. We developed a method of evaluating the binocular function using dichoptic stimulation and analysis with the Fast Fourier Transform (FFT) program[7]. With this method (stimulating each eye with different rates of pattern reversal), the activity of both eyes can be evaluated simultaneously. We were able to note the activity of each eye as a separate power in the power spectrum. In addition, we identified an intermediate component that appeared only in the state of fusion and was accompanied by a corresponding perceived change of stimulus frequency. We report here the effect of contrast change on both the monocular and binocular components of the VER.

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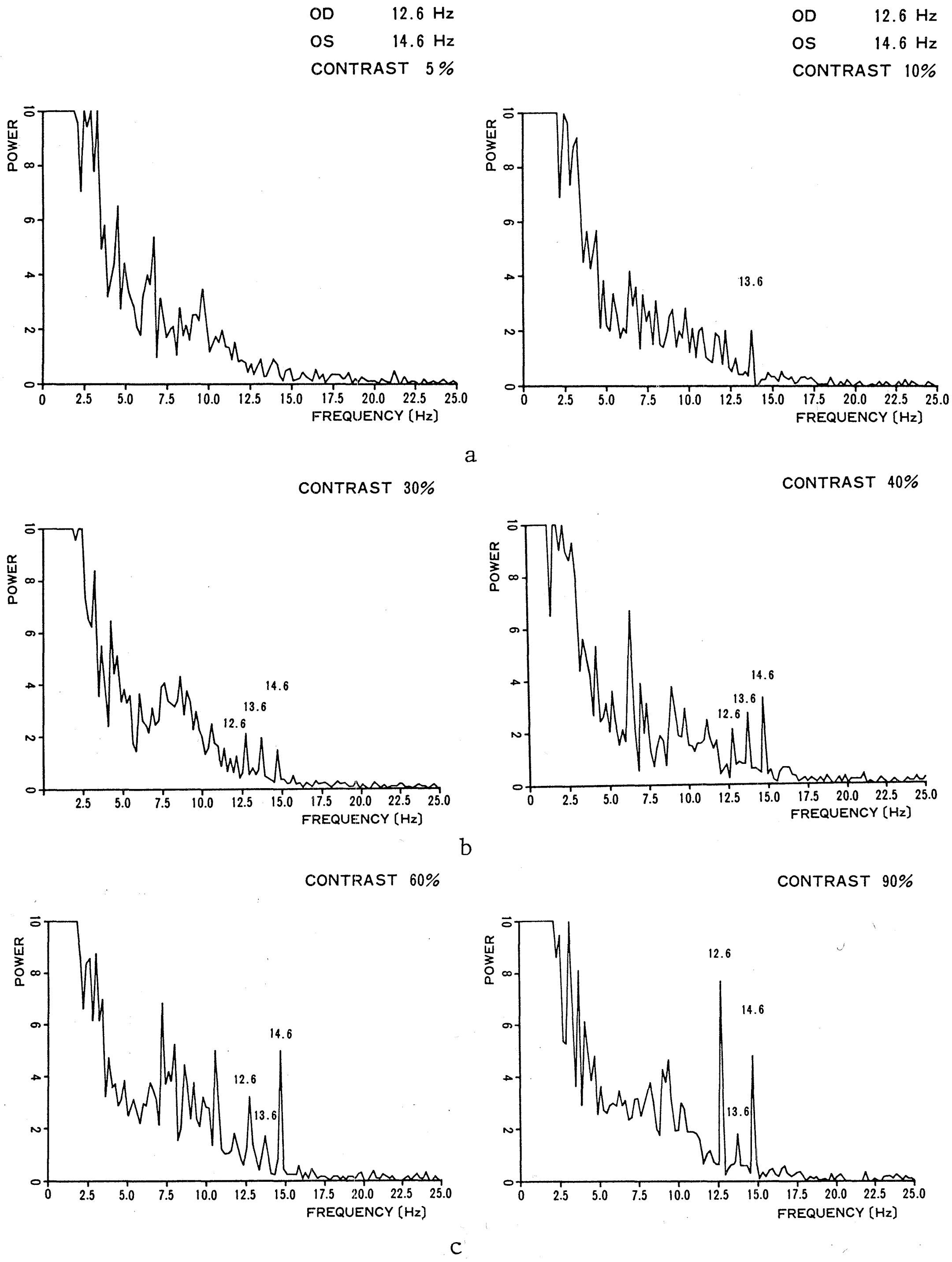
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Subjects and Methods

The subjects were four volunteers with normal binocular function. Their ages ranged from 20 to 32 years.

The method and system for recording binocular VER have been reported in detail[8]. Briefly, binocular vision is dissociated by two pairs of polaroid filters and polaroid glasses. Using the programmable mode of pattern generator (Visual Stimulator, Medelec, England), a checkerboard pattern reversal stimulus of different temporal frequency is presented to each eye simultaneously. The dissociated images are completely fused with the help of macula-size fusional targets (Nos. 118a and 118b, AFIM, Toulouse, France) placed at the center of each hemiscreen of the television monitor, and base-out prisms. The active recording electrode is placed 3 cm above the inion on the midline. The reference and ground electrodes are placed on both earlobes. The recorded VER is stored in a magnetic data recorder (DF 3515, Sony Corp., Tokyo) and later analyzed by the FFT program of the data processor (ATAC-450, Nihon Kohden, Tokyo); the power spectrum is plotted on the X-Y plotter. Each sampling period lasts about 5 seconds, and 15 samplings are averaged.

The present study consisted of two experiments. In the first, the contrast of the checkerboard stimulus pattern was the same for both eyes and was set as 5%, 10%, 20%, 30%, 40%, 60% and 90%, successively, and only the temporal frequency differed. In the second experiment, both the stimulus contrast and the temporal frequency differed between the two eyes. The contrast of one eye was fixed at 30% and the contrast of the other eye was successively set at 2%, 5%, 10%, 20%, 30% and 90%. In both experiments, the checkerboard element size was fixed at 20 minutes of arc, and the mean luminosity of the stimulus surface was 50 Cd/m^2. However, with the use of two pairs of polaroid filters, the mean luminosity fell by about 1.0 log unit.

Results

1. *Effect of binocular change of contrast*

At all contrasts, a dichoptic stimulation of 12.6 reversals/sec was delivered to the right eye and 14.6 reversals/sec to the left eye. When patterns that differ only in temporal frequency are fused, a subjective change of temporal frequency takes place. The temporal frequency that one sees subjectively is lower than the higher frequency (14.6 reversals/sec, in this case) and higher than the lower frequency (12.6 reversals/sec, in this case). All subjects perceived the subjective change of stimulus frequency. Figure 1a (left) shows the power spectrum of the binocular VER recorded when the contrast of the stimulus pattern was 5%. On the power spectrum, neither the

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Figure 1. Power spectrum of binocular VER. Abscissa shows temporal frequency and ordinate shows power of Fast Fourier Transform.

1a. (Left) At contrast of 5%, neither monocular nor binocular components are identified. (Subjective change of temporal frequency was perceivable in all subjects.) (Right) At contrast of 10%, monocular components are not clearly identified but binocular component is evident at 13.6 Hz.

1b. (Left) At contrast of 30%, both monocular (12.6 and 14.6 Hz) and binocular (13.6 Hz) components are evident. (Right) At contrast of 40%, power of monocular components shows slight increase but binocular component is stable.

1c. (Left) At contrast of 60%, power of monocular components shows further increase while power of binocular component is stable.

monocular nor the binocular component was clearly evident. Figure 1a (right) shows the power spectrum for contrast 10%. In this condition, monocular components corresponding to the stimulus to each eye are not clearly evident, but the binocular component can be identified in an intermediate position on the power spectrum (13.6 Hz).

Figure 1b shows the power spectrum obtained when the contrast was 30% (left) and 40% (right). The monocular components (12.6 and 14.6 Hz) increased with an increse of contrast, but the binocular component showed little change. Figure 1c shows the results when the contrast was 60% (left) and 90% (right). The monocular components showed a slight tendency to saturate, but the binocular component did not change significantly. Figure 2a shows the effect of contrast change on the monocular components for two subjects. The power of the monocular components increased linearly until 60% contrast. Figure 2b shows the effect of contrast change

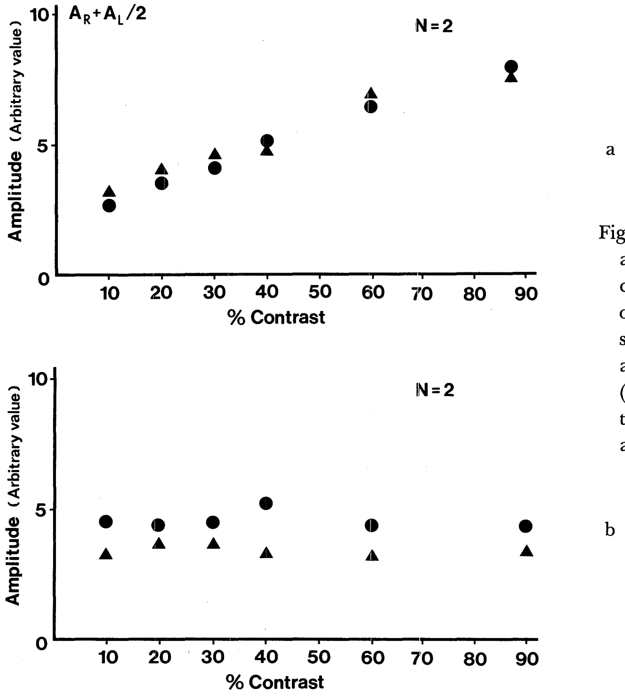

Figure 2. Effect of contrast on average monocular and binocular components in two subjects indicated by symbols. Abscissa shows contrast, and ordinate shows amplitude of VER (in terms of square root of power). (a) Monocular component, average of component for right (A_R) and left eye (A_L), shows slight tendency to saturate above contrast of 60%. (b) Power of binocular component is almost stable in all testing conditions.

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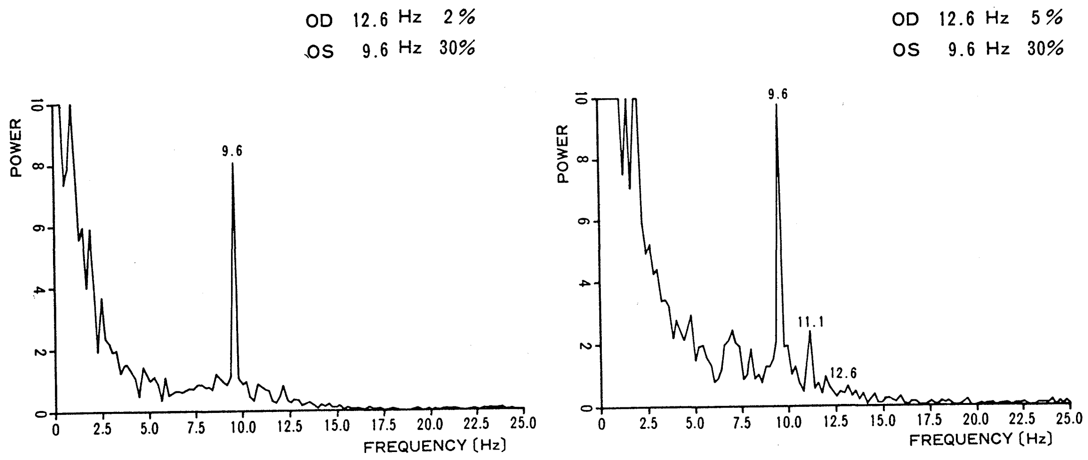
Figure 3. Power spectrum of VEP. Contrast to left eye was fixed at 30% and contrast to right eye changed. Monocular components: 9.6 Hz in left and 12.6 Hz in right eye; binocular component: 11.1 Hz.

3a. (Left) Contrast to right eye was 2%; only recognizable component is from left eye. (Right) Contrast to right eye was 5%; binocular component is identified, but power from left eye is still dominant on power spectrum.

3b. (Left) Contrast to right eye was 10%; power from right eye is on noise level. Binocular component and monocular component from left eye are evident. (Right) Contrast to right eye was 20%; both monocular components are evident, and power of binocular component is stable.

3c. (Left) Contrast to both eyes was 30%; power from both eyes is almost equal, and power of binocular component is stable. (Right) Contrast to right eye was 90% and to left eye 30%; power from right eye is larger than power from left eye. Power of binocular component is stable.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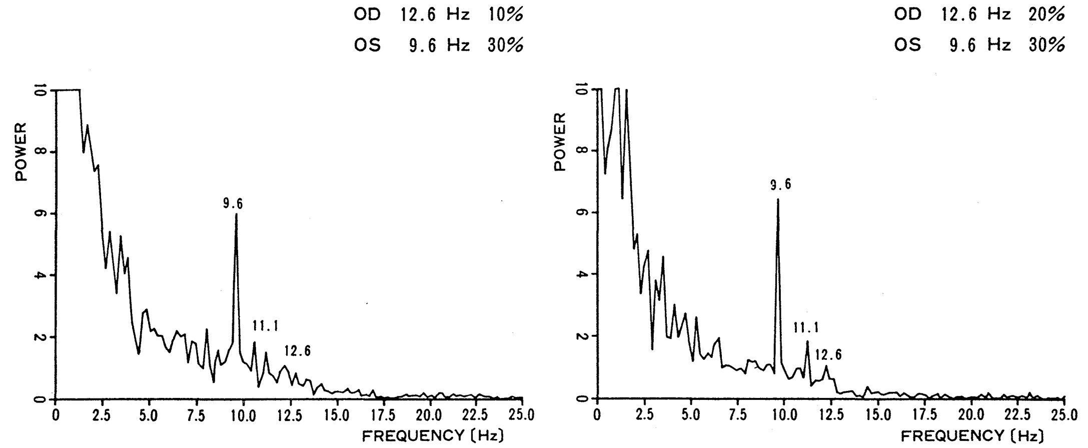
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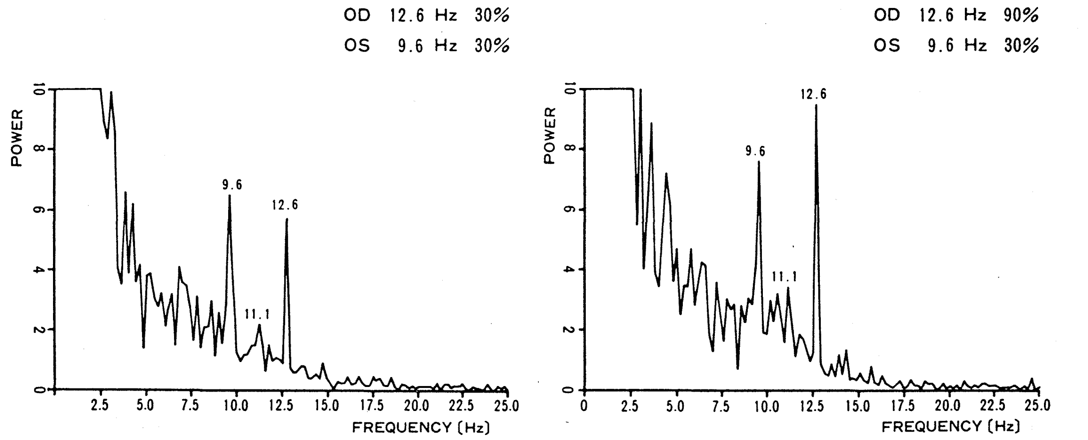
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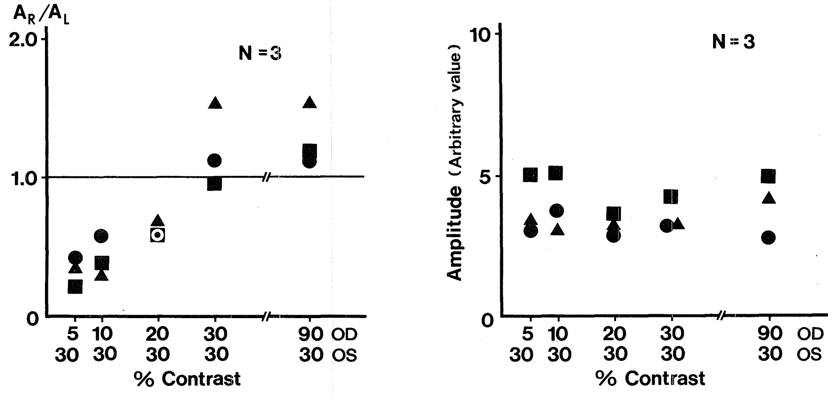

Figure 4a

Figure 4b

Figure 4. (a) Effect of monocular change of contrast on monocular component in 3 subjects indicated by symbols. Contrast to left eye fixed at 30% and contrast to right eye changed. Abscissa shows contrast and ordinate shows ratio of amplitude of right eye (A_R) to that of left eye (A_L). Amplitude ratio increases with increasing contrast. (b) Effect of monocular contrast change on binocular component. Amplitude is stable in all test conditions.

on the binocular component. The power of the binocular component remained unchanged throughout the recordings.

2. *Effect of monocular change of contrast*

At all contrasts, a dichoptic stimulation of 12.6 reversals/sec was delivered to the right eye and 9.6 reversals/sec to the left eye. The contrast to the left eye was fixed at 30% throughout the experiment. Figure 3a (left) shows the results when the contrast of the stimulus pattern to the right eye was 2%. On the power spectrum, a component from the left eye is clearly noted, but a component from the right eye and the binocular component are not evident. In Figure 3a (right), the contrast presented to the right eye was 5%. Again, the power from the left eye is dominant and the power from the right eye is very small. The binocular component was evident in the intermediate position (11.1 Hz). Under this recording condition, the subjective perception of change of stimulus frequency occurred.

In Figure 3b, the contrast to the right eye was 10% (left) and 20% (right). The component from the right eye was still very small, but the magnitude of the binocular component remained constant. In Figure 3c the contrast to the right eye was 30% (left) and 90% (right). The components of both eyes were almost equal when the contrast was at the same level (30%), but when the contrast of the right eye exceeded that of the left eye, the component from the right eye was higher. However, the binocular component remained constant. Figure 4a shows the effect of contrast change on the monocular component in 3 subjects. In all subjects, the amplitude of the monocular component of the right eye increased linearly with increased contrast of the pattern stimulus to the right eye. Figure 4b shows the effect of a monocular contrast change on the binocular component. As in the first experiment, the binocular component was stable in all conditions. The binocular component appeared even when the difference in contrast between the stimuli to both eyes was large.

Discussion

Lehmann & Fender[4] measured the flash VER amplitude while presenting a stationary pattern to the fellow eye. They reported that the VER amplitude decreased as the contrast of the pattern presented to the fellow eye increased. Kawasaki et al[3] investigated binocular function by rotating the dove prism, producing a cyclotorsional disparity between the images seen by both eyes. They found that when the degree of cyclotorsion was very small, binocular facilitation in VER was recognized, and when the degree of cyclotorsion became larger, suppression in VER was recognized.

Harter[2] reported that when the dissimilarity between the stimuli presented to both eyes was very small, the cortical unit for the binocular receptive field responded very well, but when the dissimilarity was very large, rivalry occurred between the two eyes and one eye was suppressed. Abe[1] measured the amplitude of pattern appear-disappear VER while presenting a stationary pattern of the same spatial frequency to the fellow eye. He found that the VER amplitude decreased as the contrast was increased in the fellow eye.

Lennerstrand[5] was the first to use dichoptic presentation of checkerboard patterns with different temporal frequency to each eye in the evaluation of binocular function using VER. The disparity between the temporal frequencies caused a binocular interaction between the two eyes, and in normal subjects this resulted in a decrease in the amplitude of the VER. Later, Lennerstrand & Jakobsson[6] reported that the effect of fusion did not cause any change in the amplitude of VER recorded from either eye.

The advantage of our recording system is that it allows detection and monitoring of both the binocular component and the monocular component. In addition, our method utilizes fusional targets, which facilitates the measurement of binocular function in the state of complete fusion and the monitoring of the fusional state.

In our first experiment, the saturation phenomenon was not clearly evident in the monocular components. The binocular component was not affected by the change of contrast. Once the binocular components were recognized, their amplitudes were constant. The amplitude of monocular VER increased with increasing contrast up to 60% contrast. Spekreijse[10] reported that the level of saturation moves to the higher contrast level when the level of mean luminosity is low. In our experiment, the level of mean luminosity was about 5 Cd/m^2, which is very low compared to the levels used by most investigators. We speculate that the mean luminosity decrease caused by the use of two pairs of polaroid filters may have raised the level of saturation. This difference in response between the binocular and the monocular components might be explained by the difference in saturation level. Binocular VER shows a much lower level of saturation than does monocular VER[10]. Whether this is due to the summation effect or is a property of the binocular system is still unclear.

In our second experiment, the stimulus to one eye was fixed at 30% contrast. It is important to note that the binocular component was evident even when there was a significant difference in the contrast between the two eyes. In addition, in the complete fusional state, a subjective change of stimulus frequency was also recognized. These results suggest the existence of a compensating function of the binocular system against the unbalanced visual input.

When stimulus patterns of different contrasts were presented to both eyes, the peak corresponding to the lower contrast showed lower magnitude on the power spectrum. The signal from the response elicited by the lower-contrast stimulus pattern was probably suppressed by the higher-contrast stimulus pattern presented to the fellow eye.

Our results indicate that the power of the binocular component is relatively stable whether the contrast is altered monocularly or binocularly. On the other hand, the monocular components are much more influenced by the contrast change than is the binocular component. The probable basis of the all-or-none type of response shown in the binocular component is saturation at low contrast. We also recognized the existence of some degree of a compensating mechanism for the binocular system against the unbalanced visual input. However, additional clinical and basic research is necessary for a more complete understanding of the nature of the binocular system.

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