Binocular interaction in normal vision studied by pattern-reversal visual evoked potentials (PR-VEPS)

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Monocular and binocular visual evoked potentials (VEPs) in response to different check sizes (15-21-38-84 minutes of arc) were studied in 14 subjects with normal visual acuity and stereopsis. The binocular VEP amplitude is slightly higher than the VEP amplitude on stimulation of the “better eye” and significantly higher than the VEP amplitude on stimulation of the “worse eye”; this effect is observed using small checks and almost exclusively involves N75-P100. Both the N75 and P100 peaks occur earlier after binocular than monocular stimulation. The shortening of the N75 mean latency is significantly greater than that of the P100 mean latency when larger check sizes are used. The mean latency of the N145 potential is not significantly different in monocular and binocular stimulus conditions. The slight summation effect and latency shortening in the binocular VEPs are not consistent with the hypothesis that it is the sum of separate monocular signals originating from the visual cortex that gives rise to the response. The early components of both monocular and binocular VEPs are thought to be of post-synaptic origin (outside layer 4c of area 17), where the inputs become mixed so that most cells receive information from both eyes. The amplitude enhancement of binocular VEPs, which mainly occurs when using small checks, may be related to the increase in the total amount of cortical activity representing the macular region; this may account for binocular superiority in fine spatial resolution. The latency shortening in binocular conditions can be explained by considering that the critical determinant of the latency is the fundamental spatial frequency of the pattern. When coarse patterns are used, their effectiveness in parafoveal stimulation may affect the VEPs, with a significant contribution coming from the more peripheral retina. The enlargement of the visual field when the eyes see simultaneously may therefore further reduce the latency of the response when using the larger checks suitable for eccentric stimulation.

Key Words: VEPs — Binocular vision — Monocular vision — Visual acuity — Stereopsis.

Introduction

Binocular interaction in response to transient stimulation of both eyes has been investigated by VEP testing in an attempt to correlate certain aspects of the psychophysical data with objective electrophysiology. Vision with both eyes enlarges the visual field and leads to greater visual acuity than monocular vision: Campbell and Green [8] have shown that monocular human contrast sensitivity is about 1.4 times less than binocular sensitivity. Since the early studies [15, 38], it has been observed that binocular VEPs have greater amplitude (binocular summation) than monocular VEPs under conditions in which identical patterns are presented to the corresponding retinal points (dioptic viewing condition), with a greater amount of binocular summation in the case of evoked responses to grating patterns for fine elements subtending 10-20 minutes of visual angle. These findings have been further confirmed in other studies, in which various VEP test techniques have been used to assess binocular competence in humans [2, 6, 14, 16, 17, 20]. All of these results have led to the conclusion that the binocular response has more amplitude than the monocular response. However, the hypotheses suggested by the various authors in an attempt to explain their data are far from being entirely convincing. The main aim of our investigation was to establish correlations between the different stimulus conditions (monocular and binocular) and VEP changes, using experimental conditions that have been described elsewhere in previous reports. We devoted particular attention to different aspects of the visual response: a) VEP components are generated at different levels of the visual cortical areas [4, 7, 12, 18, 19, 27, 29, 34], and so we analyzed the changes in individual peaks and waves (N75, P100, N145) in greater detail; b) VEP components may be related to the sampling of the visual stimulus, above all in the spatial frequency domain [35]: the check pattern is a complex sti-
The mean latency of the binocular N75 decreases on increasing the check size. At the 15 minute check, the interocular difference is significant (P < 0.001). The binocular N75 is significantly shorter than the worse monocular N75 (P < 0.001) at any check size, and is significantly shorter than the better monocular N75 at the 38-84 minute checks (P < 0.01 and P < 0.05, respectively). The mean latency of the binocular P100 is shorter than that of the monocular P100 at all check sizes but the difference is significant only between binocular VEP (BIN) and the worse monocular VEP (E2): P < 0.001 at the 15 minute check and < 0.01 at the 21-38-84 minute checks.

**Method**

We recorded VEPs in response to monocular and binocular stimulation in 14 normal subjects (9 F, 5 M), aged 22-48 years, with normal visual acuity and stereopsis (tested using a Stereo Optical Vectogram). The stimulus consisted of an alternating checkerboard displayed on a TV screen located at a distance of one metre from the eyes of the subject (this being a distance at which the screen subtends an angle of 30°). During the test the patient was invited to stare fixedly at a target situated at the centre of the screen (checks whose angular size was slightly less than that of the fundamental element in the pattern). The recordings were made under conditions of mesopic adaptation, at a mean pattern luminosity of 60 cd/m², for 70% contrast. The frequency of reversal was 0.80 c/sec. Three recording electrodes (monopolar needle electrodes measuring 1.2 cm in length) were respectively applied 3 cm above the inion (at the Oz point) and symmetrically on either side of the midline. The common reference electrode was placed in the fronto-polar district. The EEG signal recorded from the scalp was amplified using filters with a bandpass of 2-200 Hz; the evoked potentials consisted of averaging 100 artefact-free responses (automatic rejection was set as a function of sensitivity). The post-stimulation analysis time was 500 msec; the signal was stored on a floppy disk, from which it was processed off-line. The stimulus was electronically run by the same appliance used for the recording (Basis EP Myograph). Each test was repeated twice. Amplitude was assessed by measuring the N75-P100 deflection and the following P100-N145: in the former case, by identifying the amplitude of the N75 component and, in the latter, the amplitude of the P100 component. The right eye, the left eye and then both simultaneously were stimulated by using various checks with sides measuring 84, 38, 21 and 15 minutes of arc, corresponding to the fundamental spatial frequencies of 0.5, 1.1, 2.0 and 3.0 c/deg. The signal from the Oz site was considered for statistical analysis: the VEPs obtained in response to binocular stimulation were compared with those obtained in the so-called “better eye” and “worse eye” [25], the former meaning the eye in which the VEPs had shorter latencies and/or greater amplitudes (these variables may not be correlated). Statistical analysis was carried out using ANOVA for repeated measures and Bonferroni’s t-test.

**Results**

At all the check sizes analyzed, and for each of the components, the VEPs presented shorter latencies in response to stimulation of the right eye in 52% of cases, as against 48% of cases in which the left eye was stimulated. The mean VEP latency obtained in the right eye was not significantly different from that obtained in the left eye. The mean latency and amplitude values for each of the VEP waves are summarized in the table. The mean N75 latency obtained from the "better eye",...