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Visual evoked potentials specific for motion onset

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Abstract. Motion-onset visual evoked potentials were studied in 140 subjects by means of motion-onset stimulation either on a television screen or through back projecting via a moving mirror. The motion-onset visual evoked potentials were characterized in 94% of the population by a dominant negative peak with latency in the range of 135–180 ms. Motion-onset visual evoked potentials with a dominant positive peak, as described in the literature, seemed to be a variant of pattern-off visual evoked potentials, caused by the pattern-disappearance effect at the onset of motion with a high temporal frequency (the multiple of the spatial frequency of the structure and the velocity of motion) of more than 6 Hz. Such visual evoked potentials occur mainly when the stimulus is limited to the macular area only. Additionally, other stimulus and recording conditions were found to be suitable for acquiring the specific motion-onset potentials without their contamination by pattern-related components. These conditions were as follows: an aperiodic moving pattern (e.g., random dots) with a low contrast (<0.2); a short duration of motion (≤200 ms) and a sufficient interstimulus interval (at least five times longer than the motion duration) to decrease the adaptation to motion; and extramacular stimulation and recording of visual evoked potentials from unipolar lateral occipital leads. Such leads should be used because of the lateralization of these visual evoked potentials (mainly to the right occipital area), which is consistent with their assumed extrastriate origin.

Abbreviation: TF—temporal frequency

Introduction

The great limitation of all commonly used pattern visual evoked potentials (VEPs) is that their amplitudes decrease substantially in extramacular stimulation. Therefore, they cannot be used for testing visual pathway abnormalities affecting the more peripheral regions of the visual field. We studied the use of motion stimulation for VEP acquisition because of the reportedly higher sensitivity to motion of the peripheral retina [1, 2], likely caused by different properties of peripheral retinal M-cells in comparison with the P-cell system, which is more sensitive to the detection of a fine structure [3–6]. Moreover, the motion-related VEPs could increase the sensitivity of VEP examinations because they might be able to test the motion-sensitive parallel pathway in the visual system, which is not tested by all VEPs used presently in clinical practice.

Subjects and methods

One hundred and forty healthy, light-adapted volunteers (with Snellen acuity of at least 5/8, with correction when necessary) from 19 to 50 years of age were examined. The visual moving stimuli either were generated on a television screen (10° target) by means of a microprocessor-controlled stimulator [7] or were back projected via a moving mirror (Optical Scanner, General Scanning, USA) onto a 20° circular stimulation field. The fixation point of 15′ was placed in the center of the stimulus field, and the subjects were instructed not to follow the moving pattern with their eyes (verification with electro-oculography was done in some cases). The following stimulus patterns were used: horizontally moving grating, checkerboard, random dot structure and dot matrices. The characteristics of stimulation were as follows: pattern element size, 5′–120′; contrast, 0.05–0.95; luminance, 0.001–80 cd/m^2 (background luminance of 1 cd/m^2); velocity of motion, 0.2–100 deg/s; duration of motion, 20–500 ms; and interstimulus interval, 300 ms–4 s. Whole-field stimulation and separate stimulation of either macular or more peripheral retinal areas were employed (up to 50° tested with the use of an eccentric fixation point 50° from the edge of a standard 20° stimulus target).

Binocular VEPs were recorded from monopolar leads O_Z, O_R and O_L (5 cm to the right or left from the O_Z position, with linked earlobes serving as a reference) and from the bipolar lead O_Z–C_Z. After amplification by Tektronix AM 502 amplifiers in the 0.1- to 100-Hz band, 40–100 single evoked responses (400- to 1000-ms segments with a resolution of 1–2 ms) were averaged (the trigger for recording/averaging was at the beginning of motion).

Results

Our ongoing experiments have been oriented mainly to motion-onset reactions, which are larger and more consistent than motion-offset responses. The same findings were achieved both with motion stimulation on a television screen [7] and by the use of back projection via a moving mirror.

In 94% of our subjects, the motion-onset VEPs were characterized by a dominant negative peak (Fig. 1), the characteristics of which are given in Table 1. The preceding positivity was not constant (it was completely missing in 14% of subjects; see the bottom trace in Fig. 1), and in only 6% of subjects did this positive peak prevail over the negative. Our results agree with the findings of Yokoyama et al. [8] and Göpfert et al. [9].

However, in the little literature that exists on this topic, there are also conflicting data. A series of reports from Amsterdam [10–12] describes dominant positivity with a latency of about 130 ms as the typical cortical motion-onset reaction.

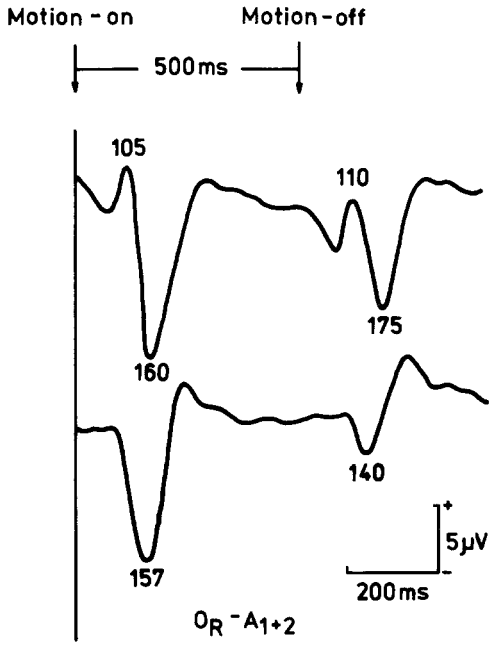

Fig. 1. Two examples of typical motion-onset/offset VEPs from the right occipital lead showing that the presence of the first positive peak is not constant. Stimulus characteristics were as follows: 10° stimulus field; checkerboard pattern (check size, 30′); luminance, 15 cd/m^2; contrast, 0.95; motion velocity, 5.6°/s.

Table 1. Latencies and amplitudes of the main negative peak of the motion-onset VEPs*

	Lead		
	O_L-A_{1+2}	O_Z-A_{1+2}	O_R-A_{1+2}
Latency (ms)	158.4 ± 9.1	156.3 ± 7.8	157.0 ± 9.0
Amplitude (μV)	7.8 ± 2.6	7.7 ± 2.8	7.9 ± 3.0

* Values were obtained in 65 subjects examined with the standard set of stimulus conditions (10° stimulus field, checkerboard pattern with 30′ check size, luminance of 15 cd/m^2, contrast of 0.95, and motion velocity of 5.6°/s).

Using a wide range of motion stimulus variables, we tried to ascertain a reason for these discrepancies and to verify the specific VEP in response to motion onset. We found that the occurrence and eventual prevalence of a negative or positive component depend substantially on some critical characteristics of motion stimulation.

Figure 2 demonstrates the effect of the temporal frequency (TF) of the motion stimulation (TF = multiple of spatial frequency [c/s] and velocity of motion [deg/s]; it is the number of pattern cycles that pass a given retinal point per unit of time), sensitivity to which varied greatly from person to

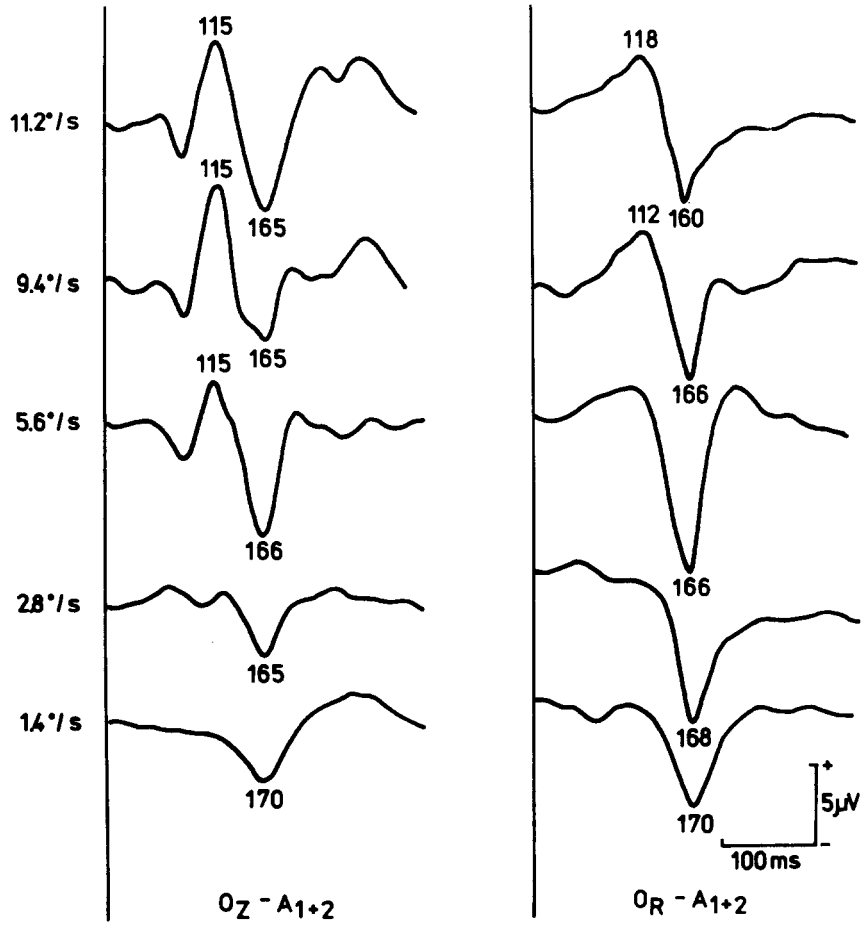

Fig. 2. Demonstration of the influence of TF on the shape of motion-onset VEPs in central (O_Z–A_{1+2}) and right (O_R–A_{1+2}) occipital leads. The motion velocity was the changing variable, and constant 30′ checks were used (all other stimulus conditions were as specified in Fig. 1). In a central occipital lead, a TF higher than 5.6 Hz (velocity of 5.6°/s with 1-c/deg spatial frequency of structure) produces a positive, pattern-disappearance–like VEP.

person. In the case presented in Fig. 2, there was a dominant positive component when a TF higher than about 6 Hz was used. This was mainly seen in the central occipital area, while the lateral leads (in this subject, the right occipital lead) displayed a dominant negativity independent of the TF.

The occurrence of the positive peak in response to high TF is likely caused by a blurring of the structure at the beginning of the motion, which evokes a positive pattern-disappearance–like component. This blurring ef-

fect can be reduced by the use of some irregular structure, or a structure with large spaces between individual elements in the axis of motion. The best results were obtained with a moving low-luminance and low-contrast random dot structure, which either evoked motion-onset responses without the positive peak (Fig. 3) or increased the amplitude of the negative peak.

A very short duration of motion (100 ms was the optimum in our experiments) and a sufficient interstimulus interval (at least five times longer than the motion duration) were necessary to avoid adaptation to motion. This allowed an increase of the negative component. It is noteworthy that the shape of motion-onset VEPs was not influenced by the motion-offset VEP in such an arrangement.

Figure 4 shows that the positive peak, when present, was prominent when macular stimulation was used, with the maximum amplitudes in the central occipital lead, whereas the negative peak was larger when there was peripheral stimulation, and its maximum was lateralized. Masking of the central 15° from the 20° stimulus target did not reduce the negativity, and in subjects with dominant positivity, the masking of the central retina changed the shape of the motion-onset VEP completely, so that the negative peak dominated.

Distinct motion-onset VEPs could be obtained up to about 50° eccentricity of the visual field. This is probably the most important finding, which promises some advantageous clinical applications of this type of VEP [13].

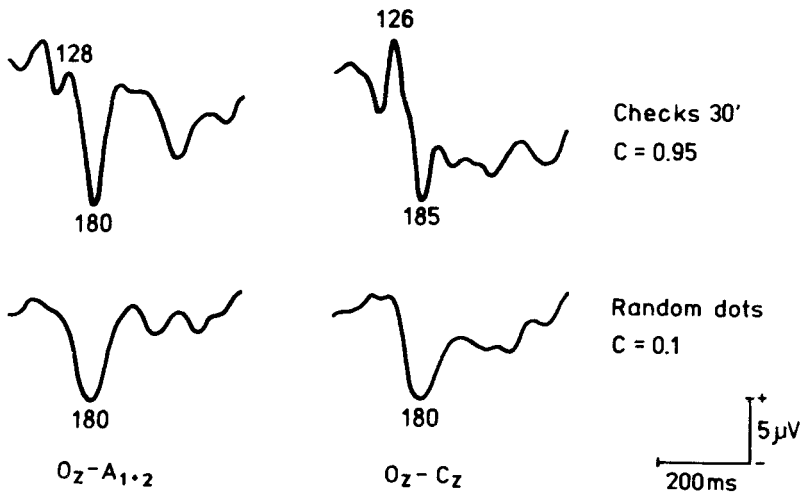

Fig. 3. Comparison of motion-onset VEPs to high-contrast checkerboard stimulus and low-contrast random dot stimulus at motion velocity of 15°/s (all other stimulus conditions were as specified in Fig. 1). When a random dot pattern is used, the positive peak in the motion-onset VEP disappears.

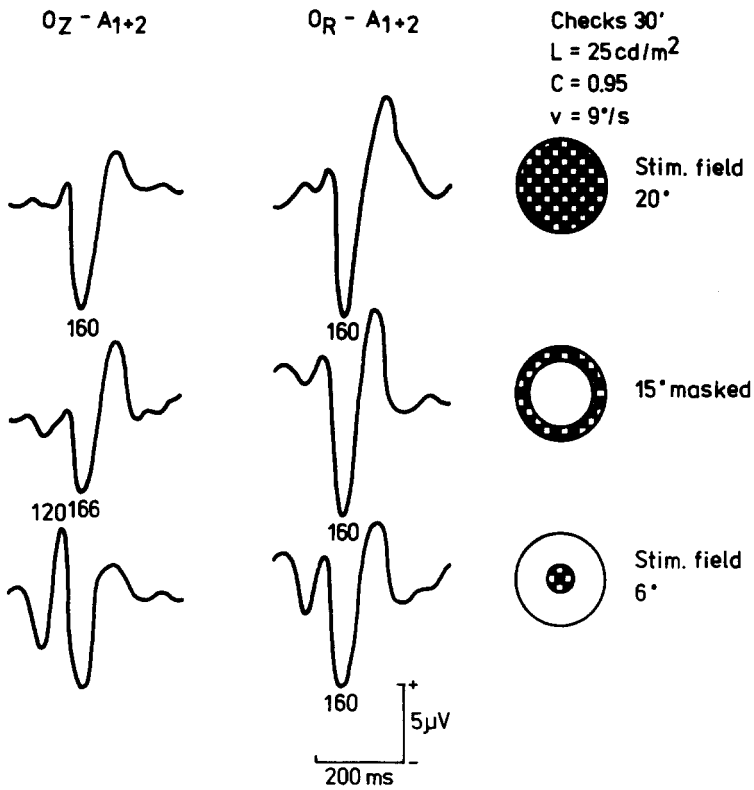

Fig. 4. The effect of macular, peripheral and full-field stimulation on motion-onset VEPs in central and lateral occipital leads. The motion-specific negative peak of the motion-onset VEPs dominates in the peripheral stimulation, whereas the positive, likely pattern-related, peak is prominent in macular stimulation only.

Discussion

On the basis of our data, we believe that the negative peak is the motion-specific component and that the positive peak in motion-onset VEPs most likely represents the pattern-dependent component.

Conflicting literature data, which attribute the positivity specifically to the motion-onset response, seem to be caused by the combination of motion stimulation variables used. The predominance of the positive peak in experiments in Amsterdam, which we believe to be primarily pattern related, can be accounted for by the equal duration of the motion and the interstimulus interval (400 ms), the limiting of the stimulus area to the central 6° only and the high TF of the moving stimulus [11, 12].

The observed lateralization of the motion-specific negative VEPs supports the hypothesis of an extrastriate localization of the visual perception of motion [14, 15].

On the basis of our results, we recommend the following stimulus and recording conditions for obtaining pure motion-onset VEPs: an aperiodic moving pattern (e.g., a variant of 'random dots') or a periodic pattern with TF not exceeding 6 Hz; a structure with low contrast (<0.2) and low luminance (<20 cd/m^2); short duration of motion (maximum, 200 ms) and a sufficient interstimulus interval (at least five times longer than the motion duration); and extramacular stimulation and recording of VEPs from unipolar lateral occipital leads.

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