Documenta Ophthalmologica **81**: 209–218, 1992.

Clinical application of motion-onset visual evoked potentials

ZUZANA KUBOVÁ & MIROSLAV KUBA

Departments of Physiology and Pathophysiology, Faculty of Medicine, Charles University, Hradec Králové, Czechoslovakia

Accepted 16 March 1992

Key words: Motion-onset visual evoked potentials, multiple sclerosis, pattern-reversal evoked potentials, retrobulbar neuritis

Abstract. The results of motion-onset visual evoked potentials and pattern-reversal visual evoked potentials were compared in 5 adults with amblyopia, in 13 patients with unilateral retrobulbar neuritis and in 62 patients with multiple sclerosis. While the pattern-reversal visual evoked potentials had reduced amplitudes and prolonged latencies in all amblyopic eyes, the motion-onset visual evoked potentials were normal. Thus, motion-onset visual evoked potentials cannot be used for diagnosis of amblyopia. In patients with retrobulbar neuritis, both types of visual evoked potentials were delayed on stimulation of the affected eye. The latency increase was, however, greater for pattern-reversal visual evoked potentials than for motion-onset visual evoked potentials. Examination of the patients with multiple sclerosis showed that the additional use of motion-onset visual evoked potentials increased the sensitivity of the investigation. In some patients, only the motion-onset visual evoked potentials had pathologic latency increases, whereas the pattern-reversal visual evoked potentials stayed within normal limits.

Introduction

At present, checkerboard-reversal visual evoked potentials (VEPs) are preferred for clinical diagnosis [1]; other stimulus forms are less frequently used, and motion stimulation is never reported. Motion-onset VEPs have, however, properties that indicate that they might give information not obtainable from other types of VEPs. For example, motion-onset VEPs are recordable up to about 50° of eccentricity [2], and their amplitudes are significantly larger to extramacular than to macular stimulation [2, 3]. Thus, motion VEPs seem to be more suitable for testing peripheral parts of the retina (e.g., in patients with glaucoma) than any other type of VEP. It is also of interest for clinical use that motion-onset VEPs are independent of the size of the stimulus elements [2, 4]. This enables testing even in patients with low visual acuity (e.g., in amblyopia). To find out whether motion VEPs are advantageous for diagnostic purposes, we compared motion and reversal VEPs in 80 patients with neurologic and ophthalmologic disorders.

Subjects and methods

Motion-onset and pattern-reversal VEPs were tested in 50 healthy, light-adapted volunteers with a Snellen acuity of at least 5/8, (20/32) after correction, if needed. The patient group included five adult amblyopic patients (aged 25 to 50 years, with visual acuities in their amblyopic eyes in the range of 5/15 to 5/50; 13 patients with unilateral retrobulbar neuritis (RBN) aged 26 to 54 years; and 62 patients aged 21 to 57 years with either definite multiple sclerosis (MS) (seven cases) or suspected MS (55 cases). Since the latter group was not categorized specifically by the referring clinician, it may also contain patients with probable MS. No patient in the MS group had a history of RBN.

All recordings were performed in a sound-attenuated, radiofrequency-shielded chamber with a background luminance of 1 cd/m^2. The subject was seated in a comfortable dental chair with neck support to reduce head movement. A fixation point of 15′ was placed in the center of the stimulus field, and the subject was instructed not to follow the moving or reversing pattern with his eyes (as was verified occasionally by means of electro-oculography). Both motion and reversal stimuli with a mean luminance of 15 cd/m^2 were generated with a microprocessor on a circular television screen subtending 10°. The motion stimulus consisted of a vertical black-and-white square-wave grating of 1.3 c/deg that moved horizontally with a velocity of 5.6°/second. Motion duration and interstimulus interval were 200 ms and 1 second, respectively. Reversal stimuli consisted of 23′ black and white checks reversing at 2.5 Hz. Monocular VEPs were recorded in the bipolar lead $O_Z - C_Z$ and in three unipolar leads with the electrodes placed at $O_Z - C_Z$ and in three unipolar leads with the electrodes placed at O_Z and 5 cm to the right and left (these electrodes were designated O_R and O_L). Linked earlobes served as references. After amplification (Tektronix AM 502) in the 0.1 – 100 Hz band, 100 responses of 400-msec duration were averaged with a sample rate of 500 Hz on a PDP-11/03 microcomputer.

Results

Control subjects

Typical pattern-reversal and motion-onset VEPs are shown in Fig. 1. In pattern-reversal VEPs, the latency of the major positive peak P_1 and its amplitude measured as $(N_1P_1 + P_1N_2)/2$ were estimated for the $O_Z - C_Z$ lead. Their means and standard deviations are given in Table 1 for left and right eyes as well as their interocular differences.

The typical shape of the motion-onset VEP either was triphasic ($P_1 - N_2 - P_2$) (in 86% of subjects), with N_2 as the most distinct and constant peak (Fig. 1), or showed only the negative N_2 peak (in 14% of subjects). In

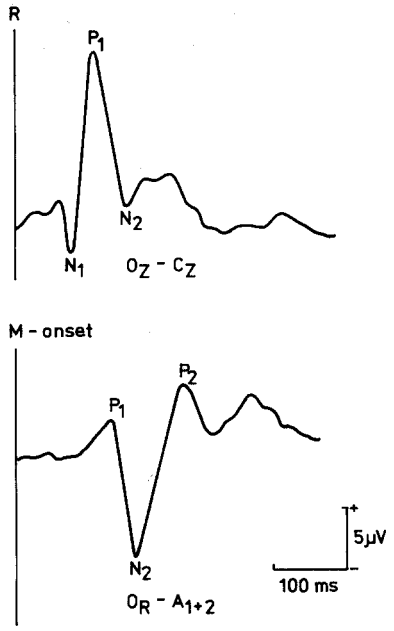

Fig. 1. Typical examples of pattern-reversal (R) VEP (with main positive peak P_1) and motion-onset (M-onset) VEP (with dominant N_2 peak).

contrast to the reversal VEPs, the motion-onset VEPs were lateralized, to the right hemisphere in 52% of the subjects and to the left hemisphere in 31%. Only in 17% of the subjects was the largest amplitude found on the midline. Since there was no significant difference in the latency of the N_2 peak among the three unipolar leads used, the latencies and amplitudes were evaluated for the channel with the largest amplitude. The mean and standard deviation of the N_2 peak latency and amplitude (estimated as $[P_1N_2 + N_2P_2]/2$) and their interocular differences are given in Table 1 for left and right eyes.

In the patients, VEPs with P_1 and N_2 latencies that exceeded the mean +2.5 standard deviations of the control group (125 and 183 msec, respective-

Table 1. Mean latency and amplitude (± standard deviation) for pattern-reversal and motion-onset VEPs in normal subjects (n = 50)

	Left eye	Right eye	Interocular difference (R-L)
Pattern-reversal			
Latency (ms)	110.2 ± 5.6	109.8 ± 6.0	2.6 ± 2.7
Amplitude (μV)	9.5 ± 3.8	9.6 ± 3.8	0.7 ± 0.6
Motion-onset			
Latency (ms)	160.3 ± 9.0	160.3 ± 8.8	4.5 ± 3.6
Amplitude (μV)	7.8 ± 3.3	7.8 ± 3.4	0.8 ± 0.7

ly) were considered pathologic. For the interocular differences, these values were 10 msec in pattern-reversal VEPs and 14 msec in motion-onset VEPs.

Patients with amblyopia

The visual acuity, latencies and amplitudes of the pattern-reversal and motion-onset VEPs are given in Table 2 for the nonamblyopic and the amblyopic eyes of the 5 subjects studied. In the amblyopic eyes, the latency of the major positive peak of the pattern-reversal VEP was always delayed (with the interocular difference exceeding the normal range in all cases) and its amplitude significantly reduced: however, the latency and amplitudes of the motion-onset VEPs were much less influenced. The interocular difference of the motion-onset latencies never exceeded the normal range, and the monocular amplitudes were comparable (Fig. 2).

Patients with RBN

All 13 patients with RBN showed either a significantly ($p < 0.001$) increased latency of the pattern-reversal VEP of the affected eye or no recordable VEP (in one patient). In all patients, motion-onset VEPs could be clearly identified, always with a significantly ($p < 0.001$) prolonged latency. Typical

Table 2 . Snellen visual acuity (VA), latencies and amplitudes of main positive P_1 peak of pattern-reversal VEPs (PREPs) and dominant N_2 peak of motion-onset (M-onset) VEPs for nonamblyopic and amblyopic eyes of 5 subjects

Nonamblyopic eye				
	PREPs		M-onset VEPs	
VA	Latency (ms)	Amplitude (μV)	Latency (ms)	Amplitude (μV)
5/5	112	5.3	156	6.2
5/5	100	11.3	152	16.4
5/5	110	6.2	160	5.6
5/5	106	12.8	160	4.1
5/5	104	11.9	172	14.9

Amblyopic eye				
	PREPs		M-onset VEPs	
VA	Latency (ms)	Amplitude (μV)	Latency (ms)	Amplitude (μV)
5/50	128	1.6	158	4.4
5/50	120	2.3	160	14.3
5/25	122	8.3	170	5.6
5/40	118	7.7	162	4.4
5/50	116	4.4	170	9.5

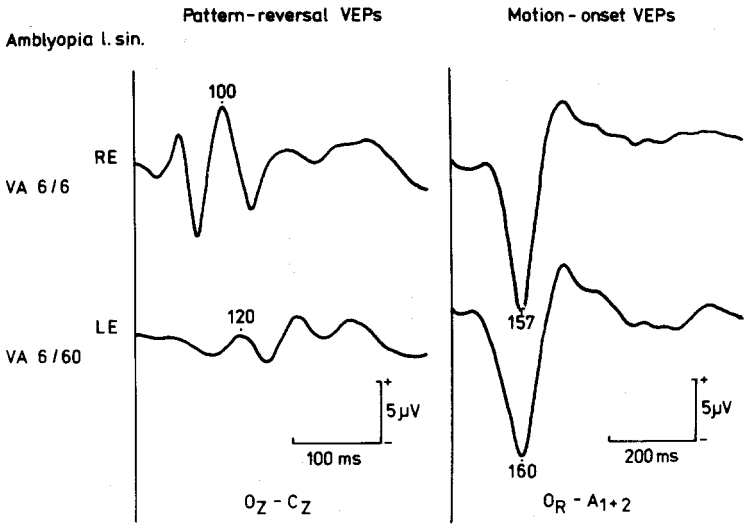

Fig. 2. Pattern-reversal VEPs and motion-onset VEPs in a patient with amblyopia. VA = visual acuity, RE = right eye, LE = left eye. Although the amplitude of the P_1 peak in the pattern-reversal VEPs is distinctly reduced in the amblyopic eye and the latency is prolonged, the amplitude and latency of the N_2 peak in the motion-onset VEPs remain unaffected.

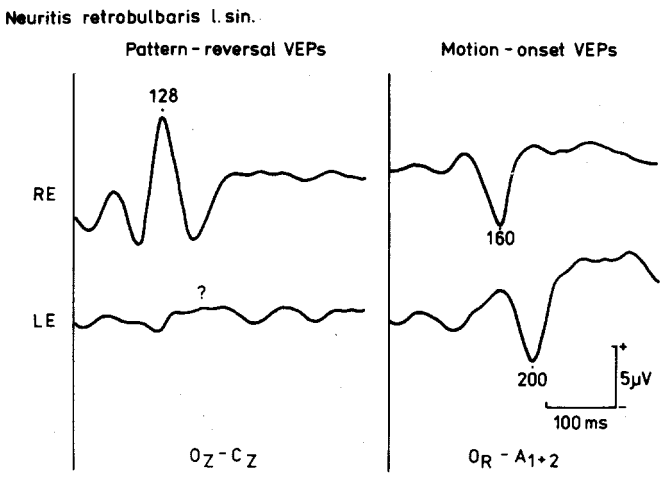

Fig. 3. Pattern-reversal VEPs of a patient with RBN. The reduced visual acuity causes a strong reduction of the pattern-reversal VEP amplitude but does not influence the amplitude of the motion-onset VEP.

examples of these pattern-reversal and motion-onset VEPs for one patient are given in Fig. 3. Thus, the results of the motion-onset and reversal VEPs were similar. However, for all subjects, the absolute value of the latency increase was greater for the pattern-reversal VEP (mean increase, 20.8 ± 12.6 msec) than for the motion-onset VEP (mean increase, 8.5 ± 9.4 msec).

The amplitudes of both types of VEPs were reduced, but always more distinctly so for pattern-reversal VEPs (with a mean interocular difference of $6.7 \pm 5.6\ \mu V$) than for motion-onset VEPs (with a mean interocular difference of $1.3 \pm 1.6\ \mu V$).

Patients with MS

In 5 of the 7 patients with definite MS, the latencies of the PREPs were delayed either for both eyes (3 patients) or for one eye (2 patients). This finding was always accompanied by a latency increase of the motion-onset VEPs in at least one eye. In the 2 patients with normal pattern-reversal VEP latencies for either eye, the motion-onset VEPs were prolonged for both eyes in one patient and normal in the other patient. The latency values are given in Table 3.

For the 55 patients with suspected MS, the mean latencies of pattern-reversal and motion-onset VEPs for the right and left eyes and their interocular differences are given in Table 4. The latencies of both types were significantly ($p < 0.01$) prolonged, and the interocular differences were also significantly longer ($p < 0.01$).

The results of pattern-reversal and motion-onset VEPs were similar in 30 patients (54.5%); both types of VEPs were prolonged in both eyes in 8

Table 3. Latencies of pattern-reversal VEPs and motion-onset VEPs for the right and left eyes and their interocular difference in patients with definite MS *

Latency (ms)					
Pattern-reversal VEPs			Motion-onset VEPs		
RE	LE	Difference	RE	LE	Difference
134	*132*	2	*192*	*196*	4
168	*156*	*13*	*206*	*200*	6
168	124	*44*	*202*	168	*34*
144	*136*	8	175	154	*21*
140	112	*28*	160	176	*16*
100	92	8	164	182	*18*
98	100	2	160	170	10

* Abnormal values are italicized.

Table 4. Mean latencies (±1 standard deviation) of pattern-reversal VEPs and motion-onset VEPs for the right and left eyes and the mean interocular differences in 55 patients with suspected MS

	Latency (ms)		
	Right eye	Left eye	Difference
Pattern-reversal VEPs	128.8 ± 16.9	122.6 ± 17.2	8.6 ± 11.3
Motion-onset VEPs	176.5 ± 20.7	174.9 ± 18.9	11.9 ± 11.8

patients, for one eye only in 7 patients, and not prolonged at all in 15 patients.

In 16 patients (29.1%), the results of pattern-reversal and motion-onset VEPs were correlated only for one eye, showing either prolonged (5) or normal (11 patients) latencies. In the fellow eyes of 11 patients, the latency of the pattern-reversal VEP was delayed and that of the motion-onset VEP was normal, or vice versa in 5 cases.

A complete discrepancy between pattern-reversal and motion-onset VEPs was found in 9 patients (16.4%). In 3 patients the latencies of the motion-onset VEPs were normal, whereas the latencies of the pattern-reversal VEPs were prolonged for both eyes. The reverse situation (normal pattern-reversal VEPs and delayed motion-onset VEPs for both eyes) occurred in 3 patients. In the remaining 3 cases, a normal motion-onset VEP was found in the eye with a prolonged pattern-reversal VEP, whereas in the eye with a prolonged motion-onset VEP, the pattern-versal VEP did not show any delay.

The findings in the definite MS and suspected MS groups and the whole group of patients with MS are summarized in Table 5. This table gives also the results of the separate use of pattern-reversal VEP and motion-onset VEP, and of combined VEP examination.

In Fig. 4, the values of pattern-reversal and motion-onset VEP latencies for all examined eyes (n = 124) of the whole group of patients with MS are plotted pairwise. This figure is indicative of the sensitivity of both types of VEPs for the diagnosis of MS.

From Table 5 and Fig. 4, it is evident that the combined use of pattern-reversal and motion-onset VEP increases substantially the sensitivity of a VEP investigation in patients with MS.

Table 5. Incidence of abnormal and normal findings of pattern-reversal VEPs (PREPs) and motion-onset (m-onset) VEPs in patients with MS

	Definite MS (n = 7)		Suspected MS (n = 55)		All patients with MS (n = 62)	
	No.	%	No.	%	No.	%
Abnormal PREPs and M-onset VEPs	5	71.4	23	41.8	28	45.2
Abnormal PREPs, normal M-onset VEPs	0	0	9	16.4	9	14.5
Normal PREPs, abnormal M-onset VEPs	1	14.2	8	14.5	9	14.5
Normal PREPs and M-onset VEps	1	14.2	15	27.3	16	25.8
Total abnormal PREPs	5	71.4	32	58.4	37	59.7
Total abnormal M-onset VEPs	6	85.7	31	56.4	37	59.7
Total abnormal findings	6	85.7	40	72.4	46	74.2

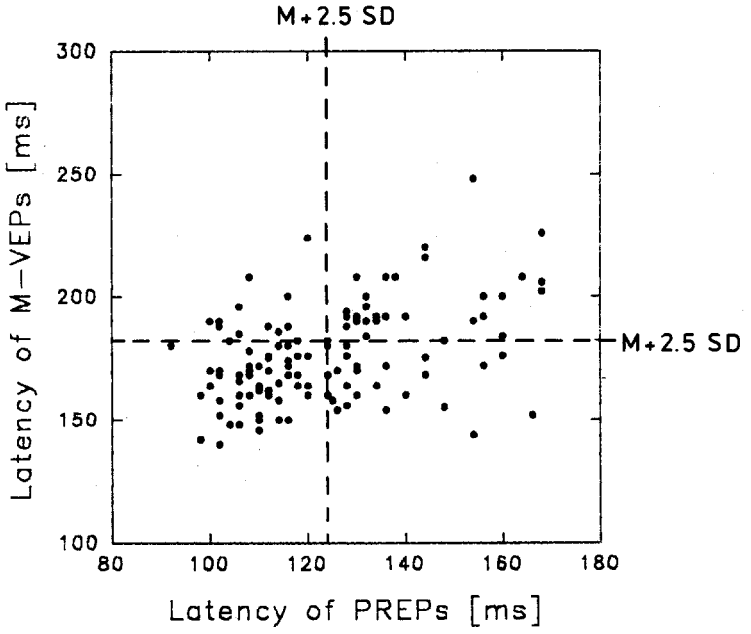

Fig. 4. Distribution of pattern-reversal VEP (PREP) versus motion-onset VEP (M-VEPs) latencies of the 124 eyes of the whole group of patients with MS. The dashed lines indicate the upper limits of both latencies (mean + 2.5 standard deviations [SD] of the values of the control group).

Discussion

There is general agreement that pattern-reversal VEPs are valuable in the detection of amblyopia [5–8], RBN [9–12], and MS [13–19], as was also indicated by the findings in this report. However, pattern-reversal VEPs test probably only one of the two parallel visual pathways [20], namely the P system responsible for detection of form, and do not verify the functional state of the second pathway (motion-specific M system). This system might be tested by the motion-onset VEPs, whose clinical use had not yet been reported.

It is not surprising that in amblyopia, which is predominantly a disorder of spatial vision [21], the motion-onset VEPs of both eyes are similar, whereas the pattern-reversal VEPs have significantly reduced amplitudes and prolonged latencies for the amblyopic eye. Thus, motion -onset VEPs cannot be used for detection of amblyopia or for monitoring treatment. They can, however, be helpful when accessory pathologic disorders affect the amblyopic eye.

In RBN, the pathologic changes of the pattern-reversal VEPs were in line with pathologic changes of the motion-onset VEPs. However, the pattern-

reversal VEPs were always more delayed than the motion-onset VEPs. This could imply that in RBN the nerve fibers of the form-detecting system are more affected than those of the motion system. Furthermore, they seem to be affected earlier, because in some of the patients the latencies of the pattern-reversal VEPs were abnormal, while those of the motion-onset VEP were within the normal range. Also, the amplitudes of the pattern-reversal VEP were much more reduced than those of the motion-onset VEP. The amplitude of the pattern-reversal VEP is often so diminished that the major positive peak is difficult or impossible to distinguish. Since the amplitudes of the motion-onset VEPs remain unaffected, these VEPs can be recorded in a larger percentage of patients than the pattern-reversal VEPs.

The main discrepancy between the motion-onset and pattern-reversal VEP results in patients with MS, i.e., prolonged latency for motion and normal latency for reversal, is important, since in those cases the pathologic changes of the optic nerve could not be assessed by the commonly used pattern-reversal VEP. Although in patients with MS the maculopapillar bundle has been reported to be predominantly affected [22–24], our results indicate that the two pathways for generating the pattern and movement VEPs might be affected differently. For that reason we recommend the combined testing of pattern-reversal and motion-onset VEP in patients with MS.

The differences in the pattern-reversal VEPs and motion-onset VEPs in patients with amblyopia, RBN and MS support strongly the hypothesis that these two types of VEPs have a different origin. For this reason, motion-onset VEPs provide additional information for clinical practice and increase the sensitivity of the VEP investigation.

References

1. Spehlmann R. Evoked potential primer: Visual, auditory, and somatosensory evoked potentials in clinical diagnosis. Stoneham, Mass: Butterworth Publishers, 1985: 85–7.
2. Kuba M, Kubová Z. Visual evoked potentials specific for motion-onset. Doc Ophthalmol 1992; 80: 83–89.
3. Kubová Z, Kuba M, Vít F, Peregrin J. Properties of movement on related VERs. Doc Ophthalmol 1990; 75: 67–72.
4. Markwardt F, Göpfert E, Müller R. Influence of velocity, temporal frequency and initial phase position of grating patterns on motion VEP. Biomed Biochim Acta 1988; 47: 753–60.
5. Arden GB, Barnard WM. Effect of occlusion on the visual evoked response in amblyopia. Trans Ophthalmol Soc UK 1979; 99: 419–26.
6. Mayeles WP, Moulholand WV. The response to pattern reversal in amblyopia. In: Gracco RQ, Bodis Wollner I, eds. Evoked potentials. New York: Alan R. Liss Inc, 1986: 243–50.
7. Levi DM, Manny Ruth E. The VEPs in the diagnostic evaluation of amblyopia. In: Gracco RQ, Bodis Wollner I, eds. Evoked potentials. New York: Alan R. Liss Inc, 1986: 437–46.
8. Sokol S. Clinical application of the ERG and VEPs in the pediatric age group. In: Gracco RQ, Bodis Wollner I, eds. Evoked potentials. New York: Alan R. Liss Inc, 1986: 447–55.
9. Halliday AM, McDonald WI, Mushin J. Delayed visual evoked responses in optic neuritis. Lancet 1972; i: 982–5.

10. Cox TA, Thompson HS, Hayereh SS, Snyder JE. Visual evoked potential and pupillary signs. A comparison in optic nerve disease. Arch Ophthalmol 1982; 100: 1603–7.
11. Sanders EACM, Volkers ACW, Van der Poel JC, Van Lith GHM. Visual function and pattern visual evoked response in optic neuritis. Br Ophthalmol 1987; 71: 602–8.
12. Brecelj J, Kriss A. Pattern reversal VEPs in optic neuritis. Advantages of central and peripheral half-field stimulation. Neuro-ophthalmology 1989; 9: 55–63.
13. Harding AM, McDonald WI, Mushin J. Visual evoked potentials in patients with demyelinating disease. In: Desmedt JE, ed. Visual evoked potentials in man. New developments. Oxford, England: Clarendon Press, 1977: 438–49.
14. Koerner E, Ladurner G, Flooh E, Reinhart B, Wolf R, Lechner H. Änderungen der Muster-evozierten Potentiale bei multipler Sklerose im Zusammenhang mit dem zietlichen Ablauf der Erkrankung. Z EEG-EMG 1982; 13: 73–6.
15. Matthews WB, Wattam-Bell JRB, Pountney E. Evoked potentials in the diagnosis of multiple sclerosis: A follow up study. J. Neurol Neurosurg Psychiatry 1982; 45: 303–7.
16. Oepen G, Brauner C, Doerr M, Thoden W. Visual evoked potentials elicited by checkerboard versus foveal stimulation in multiple sclerosis. Arch Psychiatr Nervenkr 1981; 229: 305–13.
17. Celesia GG, Kauffmann D, Cone S. Simultaneous recording of pattern electroretinography and visual evoked potentials in multiple sclerosis: A method to separate demyelinization from axonal damage to optic nerve. Arch Neurol 1986; 43: 1247.
18. Paty DW, Oger JJF, Kastrukoff LF, Hashimoto SA, Hooge JP, Eisen AA, Eisen KA, Purves SJ, Low MD, Brandejs V, Robertson WD, Li DKB. MRI in the diagnosis of MS. A prospective study with comparison of clinical evaluation, evoked potentials, oligoclonal banding, and CT. Neurology 1988; 38: 180–5.
19. Altenmüller E, Diener HC, Dichghans J. Visuel evozierte potentiale. In: Stöhr M, Dichghans J, Buettner UW, eds. Evozierte potenciale. Berlin: Springer Verlag, 1989: 279–379.
20. Lennie P, Trevarthen C, Van Essen D, Wässle A. Parallel processing of visual information. In: Spillmann L, Werner JS, eds. Visual perception: The neurophysiological foundations. San Diego: Academic Press, 1990: 103–28.
21. Wald G, Burian HM. The dissociation of form vision and light perception in strabismic amblyopia. Am J Ophthalmol 1944; 27: 950–63.
22. Feinsod M, Abramsky O, Auerbach E. Electrophysiological examination of the visual system in multiple sclerosis. J Neurol Sci 1973; 20: 161–75.
23. Hennerici M, Wenzel D, Freund HJ. The comparison of small-size rectangle and checkerboard stimulation for the evaluation of delayed visual evoked responses in patients suspected of MS. Brain 1977; 100: 119–36.
24. Gerhard H, Jörg J, Friesacher H. Zerebrale Refraktörperiod des VEP nach Ganzfeld- und fovealer Stimulation. Z EEG-EMG 1985; 16: 81–6.

Address for correspondence: Zuzana Kubová, Department of Physiology, Faculty of Medicine, Charles University, Simkova 870, 500 38 Hradec Králové, Czechoslovakia.
Phone: (49)25701.