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Cognitive Evoked Potentials Related to Visual Perception of Motion in Human Subjects

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Summary

A method was tested for simultaneous recordings of evoked potentials from the secondary visual cortex (medio-temporal) and from the brain cognitive areas (fronto-central). Visual moving stimulations with cognitive tasks seem to be suitable for combined examination of visual motion perception and cognitive processes based on the magnocellular system activity. This arrangement enhances the analysis of visual information processing and evaluation of central nervous system functions.

Key words

Cognitive evoked potentials – P300 – Visual motion stimulation – Visual perception of motion

Introduction

According to the visual stimulation used, various brain cortical areas can be activated. Perception of a simple static monochromatic pattern is completed within the primary visual centres V1 and V2, visual processing of colour and motion is accomplished in the secondary extrastriate temporo-occipital associate areas V4, V5 (Livingstone and Hubel 1988) and recognition of visual tasks is completed after activation of parietal and fronto-central associate cognitive areas of the brain (Brandeis and Lehmann 1986).

Combined visual evoked potentials (VEPs), recorded simultaneously at the mentioned cortical levels, represent a tool for complex objective non-invasive testing of visual information processing. When the primary and cognitive reactions are recorded simultaneously and the difference in their latency is evaluated (the so-called "central reaction time"), it is posssible to estimate at which brain level the processing of sensory information is impaired (Antal *et al.* 1996). This expands the clinical diagnostic applications of VEPs.

Characteristics of secondary VEPs related to visual perception of motion were already described (e.g. Kuba and Kubová 1992, Kuba *et al.* 1992, Kubová *et al.* 1995a) and also their diagnostic use was succesfully tested (e.g. Kubová and Kuba 1992, Kubová *et al.* 1995b, 1996) in combination with commonly used pattern-related VEPs.

Recently, we have been working on methods of visually evoked cognitive potentials. However, contrary to the standard way of pattern-onset stimulation (appearance of patterns or pictures representing target and non-target stimuli – see e.g. Geisler and Polich 1994, Sangal and Sangal 1996), alternatives for obtaining cognitive potentials representing visually recognised changes in direction, velocity and coherence of motion have been verified.

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Methods

A 21" PC monitor with a 75 Hz refresh rate was used for stimulation, providing a stimulus field of about 40° x 30° at the observing distance of 0.6 m. With the use of animation software (Autodesk Animator, USA) we generated the following stimuli (Kremláček *et al.* 1997):

– *Direction change*: Low contrast checkerboard (mean luminance 17 cd/m^2, 40' check size) moved at the velocity of 7°/s for 200 ms with pseudorandom interstimulus interval (ISI) within the range of 1–3 s. Oddball paradigm (see e.g. Polich 1991) was applied for recording of the cognitive responses. Direction of the movements was either to the left or right with pseudorandom sequence. Movements to the right represented rare target stimuli, which had to be recognised by subjects.

– *Velocity change*: The same pattern moved either at the velocity of 7°/s or 14°/s in pseudorandom order. The higher velocity represented the target stimululi.

– *Coherence change*: Two horizontal rows of checks moved either both in the same direction (left or right - coherent motion) or they moved in opposite directions (in pseudorandom order) – non-coherent motion. The target stimulus was the non-coherent motion.

The proportion of the target (rare) and non-target (frequent) stimuli was the same in all types of stimulation 1:3. Subjects fixating the centre of the stimulus field visually were asked to count the target stimuli.

Unipolar leads from Pz, Cz and Fz were used for recording of the cognitive potentials and lateral temporo-occipital leads (5 cm to the left and right from the Oz) served for simultaneously recorded motion-onset VEPs.

Twenty healthy drug-free subjects with normal visual acuity (10 males of the average age 34±7 years and 10 females of the avarage age 36±5 years without any other special selection) were examined with binocular stimulations at about the same day time (10:00–12:00 h). The recording session lasted for 40 min at the most and the order of specified stimuli (recorded twice) was randomly changed in each subject.

Table 1. Group mean amplitudes and the latencies of P300 wave in different motion-related cognitive tasks (lead C_z-A_2)

Cognitive task	P300 amplitude (μV)	P300 latency (ms)
Direction change	15.3±6.6	392±36
Velocity change	12.2±7.1	408±44
Coherence change	13.8±7.7	398±38

Data are means ± S.D.

Results

As a result of our cognitive stimulation, an uniform late positive wave was obtained in all stimulus variants, however, the latencies differed substantially. The shortest latency with the lowest variability of this positivity (392±36 ms) was achieved in the case of directional changes of recognition (see Table 1 for comparison). Since this variant of the tested cognitive potentials was the most promising (because of possible diagnostic applications), we tested it in more detail.

The averages of the recorded cognitive potentials (in both target and non-target stimuli) in the frontal and central monopolar leads (omitting Pz which gave about the same results as Cz) are compared in Fig. 1. The first negative peak with the latency of about 165 ms represents the motion-on related potential. This component dominated in the lateral occipital leads with non-significant differences between the target and non-target stimuli. The cognitive potentials, that reflect the direction discrimination, consist of a single broad positive wave which resembles a P300 peak recordable *via* standard acoustic or visual cognitive stimulations. This positivity dominated in the central and frontal locations and was significantly reduced in non-target responses.

Figure 2 presents the individual recordings from all 20 subjects and shows the rather large interindividual variability of the tested cognitive response (P300). However, the peak latency variation coefficient ([S.D./Mean]x100) was of about 9 % only and the relative narrow range of normal latencies (302– 482 ms in case of using M±2.5 S.D.) makes it possible for pathological differentiation. Even smaller intraindividual variability was observed, mainly in more experienced subjects. This confirms the known fact that longitudinal studies with evaluation of intraindividual changes represent a better application of cognitive potentials for diagnostic purposes.

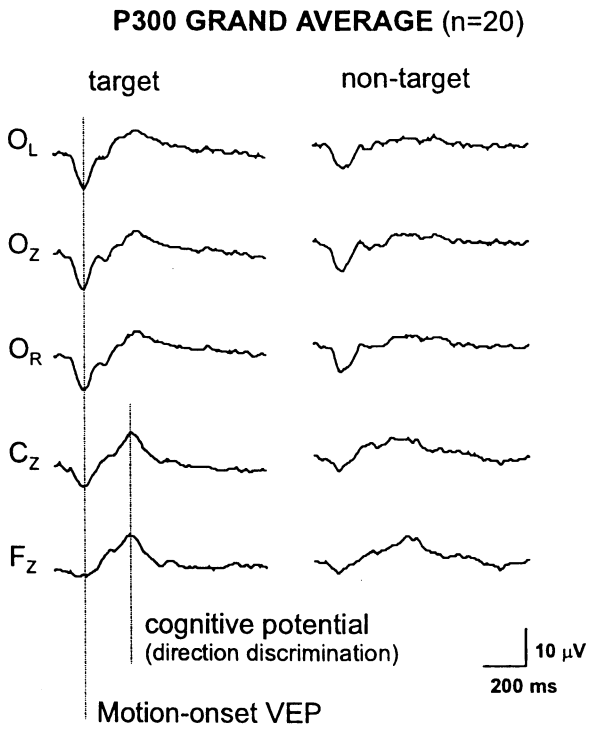

Fig. 1. *Cognitive potentials evoked by direction changes in visually perceived motion.*

No significant differences were found between males and females and the rather small group of subjects aged 20–49 years did not display any correlation between P300 parameters and age.

Preliminary attempts were also made to verify some diagnostic possibilities of the described variant of visually evoked cognitive potentials. An example in Figure 3A shows a patient with multiple sclerosis (MS) in whom both primary (pattern-reversal) and secondary (motion-onset) VEPs latencies were normal. This means that the parvocellular and magnocellular systems were intact. Exclusively delayed cognitive EPs point to demyelination in the higher order associate brain areas. The second example in Figure 3B depicts the results of EPs examination in a case of bilateral intraocular hypertension exhibiting prolonged latencies of all the examined evoked potential (EPs) types (pattern-reversal, motion-onset VEPs and cognitive EPs). This might be interpreted as evidence that the cause of neural transmission delay is located within the first part of the visual pathway – preceding the primary cortex – and that the disorder concerns both parvo- and magnocellular systems of the visual pathway. The third clinical case (Fig. 3C) with headache and visual halucinations shows that some visual disorders (most likely caused by associate cortex hypoxia) could be objectivised by cognitive potentials only (both pattern-reversal and motion-onset VEPs are within the normal range).

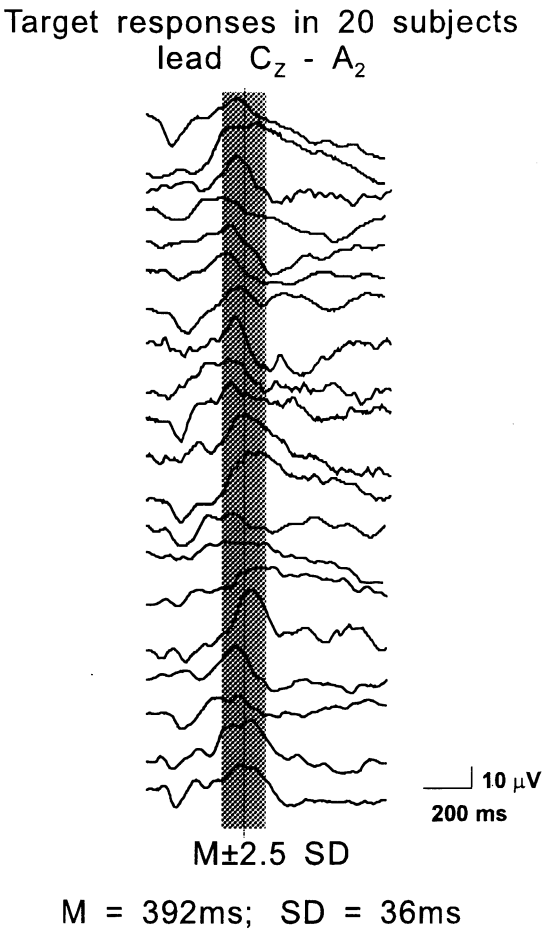

Fig. 2. *Interindividual variability in visually evoked cognitive potentials. M – mean, S.D. – standard deviation*

Discussion

Some disorders in CNS functions, which do not have any morphological basis, can be detected only *via* the visual modality of cognitive EPs (Bokura *et al.* 1994). These reactions of higher order brain areas differ both in amplitude and latency. They depend on many conditions of the stimuli and functional state of the central nervous system, but also on the individuality of each examined person. Generally, it is supposed that the relatively high inter- and intraindividual variability of the cognitive EP parameters is especially influenced by the following factors: age, sex, type of personality, level of cognitive abilities, seasonal and diurnal rythm, the menstruation cycle, body temperature and food acquisition (Polich 1991, Kügler *et al.* 1993). These factors can influence the cognitive functions by means

of hormonal changes (glucocorticoids, thyroid hormones etc.), vegetative reactions and state of metabolism (glycaemia etc.) (e.g. Polich and Kok 1995). In addition, there are theories that explain the cognitive function disorders in depressive states and anxiety by changes in the level of some neurotransmitters and hormones (serotonin, GABA, melatonin etc. – Kaplan *et al.* 1994) or minerals. At present, attention is being focused, among others, on magnesium (e.g. Kirov *et al.* 1994, Joffe *et al.* 1996), the level of which is also influenced by stress (Tanabe and Noda 1992) or by plasmatic levels of epinephrine (Ryzen *et al.* 1990). Circadian changes in the levels of these substances can contribute to the intraindividual variability of cognitive EPs in healthy persons.

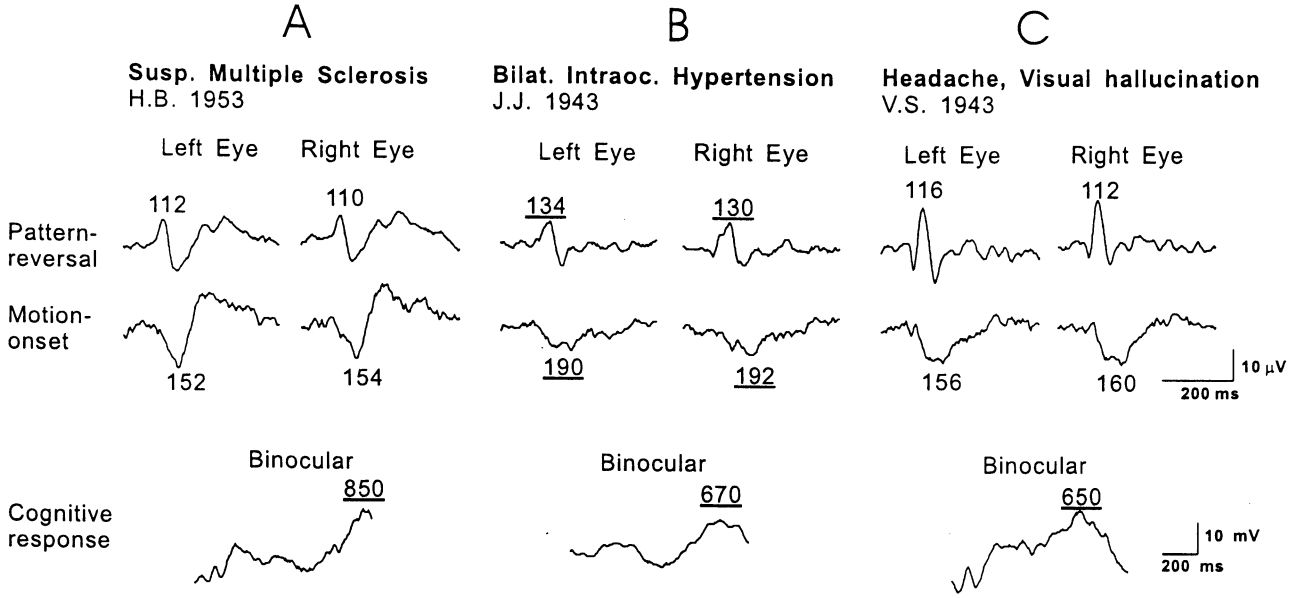

Fig. 3. *Examples of a pathological delay of cognitive responses in three clinical cases. Underlined latency values represent pathological findings.*

The above described P300 diversity in the used variants of moving stimuli can be explained by differences in the complexity of cognitive tasks. In comparison to coherence and motion velocity, the discrimination of changes in motion direction is a simpler variant of visual information processing (with respect to the existence of direction selective cells in the primary visual cortex – e.g. Mikami 1991) and does not require maximum cooperation (attention) of the subject. The shortest latencies and the lowest variability of P300 in direction recognition correspond well to this presumption. Location of the maximum cognitive response to either the frontal or central brain area is quite a common observation (Sangal and Sangal 1996) which might reflect the known non-uniformity of associate brain functions.

Despite these complicating aspects, the first positive clinical experience with diagnostic applications of the cognitive EPs has already been done. It was mainly found in subclinical encephalophaties arising from renal and hepatic failure (e.g. Cohen *et al.* 1983). Because the P300 parameters have a close relationship to basic aspects of mental functions, the evaluation of these potentials seems to be useful in cognitive disorders, especially in the diagnosis of dementias. The reduced amplitude and prolonged latency of the P300 peak were found in Alzheimer's disease (Polich *et al.* 1990). Manifestation of cognitive disorders were also detected by cognitive EPs in Parkinson disease (Růžička *et al.* 1993). In schizophrenia, a typically increased response to frequent "non-target" stimuli can be found and, because of this, a significantly reduced reaction to "target" stimuli is present (Buchwald 1986).

In neurology, the cognitive EPs can contribute to the diagnosis of demyelination diseases, namely in cognitive functional disorders without distinct impairment of sensory pathways up to the level of primary cortical centres (Polich *et al.* 1992). It seems that the visually evoked cognitive EPs may play a significant role in the diagnostics of previous asymptomatic transitory ischaemic attacks (Taghavy and Hamer 1995).

In our opinion, despite the existing positive results with the application of cognitive evoked potentials there is still the need for reducing their large variability which limits their routine clinical application. For this reason, we started to test some new variants of stimulation and that is why we will try to verify the influence of some other above mentioned factors in the future.

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