CLINICAL STUDY

Modulation of evoked potentials by interfering mental activity

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Abstract

Background: **Non-specific influences (attention, mental set, mental imagery) take part in modulation of information processing in the human central nervous system at various levels of central hierarchy.**
Objectives: **To broaden knowledge concerning the conjunction of motor control and cognition as well as to discuss some possible psychophysiological mechanisms.**
Methods: **Somatosensory evoked potentials, motor related cortical potentials and the saccadic eye movement related potentials were recorded over frontal and parietal cortices in the control condition and compared with those registered under the influence of a mental imagery task introduced as a modulatory factor. Special focus was devoted to their early components.**
Main results: **Early components of the above potentials, which are assumed to represent the coding of physical characteristics of evoking stimuli, are changed under the influence of mental activity. Frontal evoked potentials are markedly modulated as compared to those recorded parietally. In general, the results support the view that the preparation for both, real movements and mentally simulated movements share probably some common mechanisms at the cortical level.**
Conclusions: **Modulatory effects of mental activity upon the used evoked potentials point to the possible participation of the central gating mechanism, attention focussing and some other psychophysiological mechanisms related to internal representation of sequence of events. The results suggest that experimental conditions need to be exactly specified and examined subjects must be properly instructed.**
(Fig. 3, Ref. 12.)
Key words: evoked potentials, mental task, modulatory effects, psychophysiological mechanisms.

Sensory and motor information conveyed in the central nervous system are being decoded and transformed during their processing at various levels of the central hierarchy. Over the last decades evidence has been accumulated that there exist some rather non-specific neuronal circuits of the human brain which take part in modulation of the information processing with respect to the more general CNS activation level. Among such non-specific influences the focussing of the attention, mental set, or mental imagination may be mentioned (Jergelová et al, 1996).

The recording of the macroelectrophysiological correlates, i.e. the evoked brain potentials offer some information about the functional status of the neuronal circuits which participate in afferent processing of information as well as in efferent ones, that is in realisation of responses. The evoked potentials from various modalities, e.g. the somatosensory evoked potentials (SEPs), the evoked potentials time-locked to the onset of the saccadic eye movements (SEMRPs), the motor related cortical potentials (MRCPs) and others offer also the data concerning the timing characteristics of the sensory-motor transformation and they are certain reflections of the complex sensory-motor integration. The above mentioned evoked potentials allow to study the interfering mental activity influence on the sensory-motor transformation.

The sensory-motor transformation depends mainly upon the co-operation between the frontal and parietal cortical areas via the cortico-cortical and cortico-subcortico-cortical neuronal connections which are strongly reciprocal. It is supposed that many

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of these connections form rather largely segregated circuits dedicated to specific aspects of sensory-motor transformation. These „independent modules" may be then considered as the functional unit of the cortical motor system (Luppino and Rizzolatti, 2000). The fronto-parietal connections are assumed to play a significant role in cognitive functions as well. It is not surprising that Hauert (1986) has formulated the hypothesis that the motor function is a cognitive function. Between setting the purpose of movement and its actual execution, integration takes place between motivational, perceptual, and previously overlearned motor components. This may be regarded as the preparation of a motor program (de Jong et al, 1999).

The aim of this study was to broaden knowledge concerning the conjuction of motor control and cognition, based on our previous studies which are summarised and possible psychophysiological mechanisms are discussed. As a manipulation taking part in processing specific information, that means the interference of a cognitive activity, the mental imagination was used. The SEPs, MRCPs and SEMRPs served as correlates from the above point of view.

Material and methods

Three groups — each of 5—10 healthy undergraduates — selected on the basis of previous control recordings of the evoked potentials used — served as subjects in SEPs, SEMRPs and MRCPs experiments, respectively. All subjects were right-handers according to laboratory standard testing procedure (Jagla et al, 1994). A special computer programme was elaborated with the modules for particular evoked potentials used. Each module was specified in terms of trigger pulse, time-window of sweeps and sampling frequency as well. All three experiments were divided into two parts. In the first one the above evoked potentials were registered as control condition and in the second part the mental imagery as an modulatory factor was introduced.

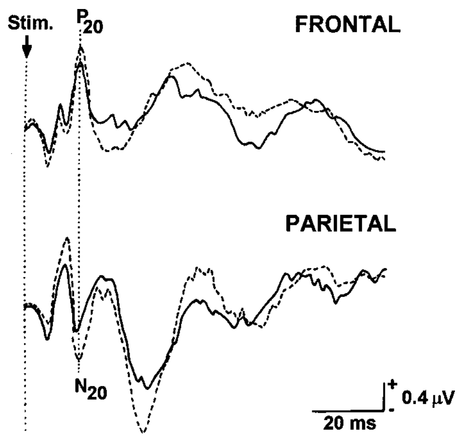

Fig. 1. The somatosensory evoked potentials registered over the frontal motor hand representation area and over the parietal sensory hand representation one. Dashed lines represent the recordings from control condition, black lines from mental interference task. The changes in the early SEP components are clearly visible.

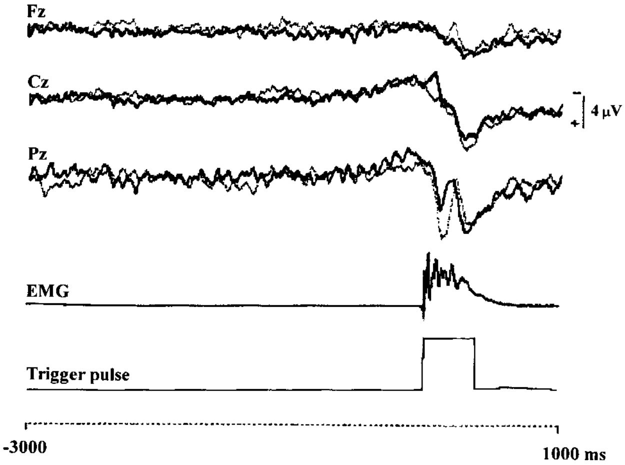

Fig. 2. Motor evoked cortical potentials registered over frontal motor areas (Fz), over vertex area (Cz) and over the posterior parietal cortex (Pz). Grey curves represent recordings from control condition, black ones from mental interference task. The changes in the motor execution components are seen under the mental movement simulation task.

Experiment 1 -- somatosensory evoked potentials

Subjects have learned beforehead a sequence of flexions and extensions of the particular right hand fingers and the opposition of thumb. SEPs were recorded during the execution of the learned sequence. In the second part of the experiment the subjects executed the same sequence and at the same time they mentally simulated the movement execution. Their attention was focussed on the fingers of that hand whose peripheral nerve was stimulated. N. medianus was stimulated with 2 Hz rectangular pulses of 0.2 ms duration. The intensity of stimulation was adjusted to elicit a just visible twitch of the thumb without causing pain. 500—1000 sweeps were recorded with time window of 5-105 ms after the trigger pulse was delivered. The SEPs were recorded over the frontal motor hand representation areas and over the parietal sensory hand representation ones as well.

Experiment 2 — motor related cortical potentials

The similar procedure was used as in the experiment 1 but the motor related cortical potentials were recorded over the frontal motor areas as well as over the posterior parietal cortices. In the first part of the experiment subjects were asked to perform voluntary self-paced movements — repetitive brisk flexions of right fingers. In the second part the mental movement simulation during the real movement execution was used as an interfering mental activity. The MRCPs consisting of 50—100 sweeps were registered using the sampling frequency of 200 Hz and the time window of 3000 ms before and 1000 ms after the simple hand flexions onset in a self-paced frequency.

Experiment 3 — saccadic eye movement related potentials

The task of the subjects was to catch with the eyes, as quickly as possible, the visual targets of 0.5° in diameter appearing at

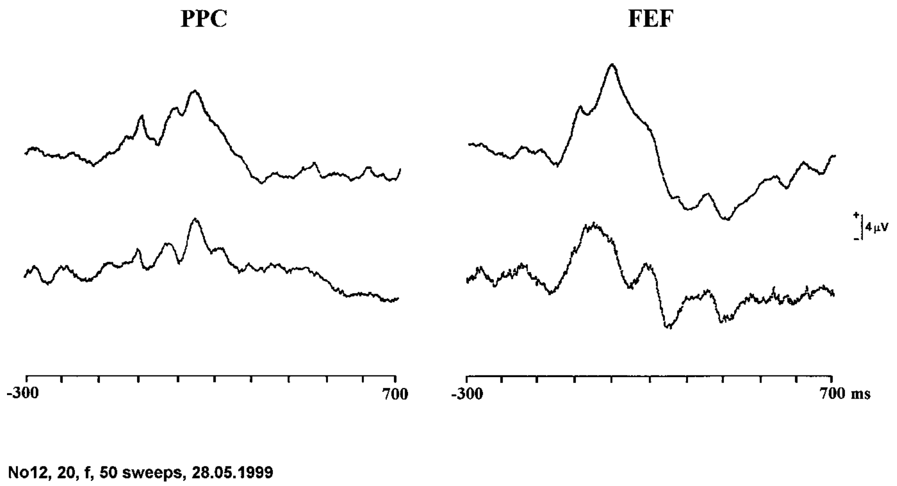

Fig. 3. Saccadic eye movement related potentials registered over the posterior parietal areas (PPC) and over the frontal eye fields (FEF). Upper traces represent control condition, lover ones the influence of the interfering mental activity. The changes of various components of the saccadic eye movement related potentials are prominent under the mental condition.

2—5 sec intervals irregularly to the right or to the left from the target actually fixated. The targets were switched on and off on a panoramic screen. In the second part of the experiment the subjects were asked to evoke a vivid image of a familiar face during the same visual fixation task. The trigger pulse was time-locked to the onset of a saccade in the electrooculogramm (EOG). The EOG was recorded binocularly and the SEMRPs were recorded over the frontal eye fields as well as over the posterior parietal cortices with the time window of 500 ms before and 1500 ms after the onset of a saccade.

Results

Experiment 1

Repeated examinations have shown that the early components of the SEPs were influenced (15 % diminution of their amplitudes, $p<0.05$) by the movement mental simulation over the both cortical areas as compared to the control condition. From the frontal complex, the component with peak latency of 20 ms was most markedly influenced by the mental simulation of motor sequence (its amplitude diminished at about 25 %, $p<0.01$, and its latency significantly shortened, $p<0.05$). Results are illustrated in the Figure 1.

Experiment 2

The several times repeated experiments have revealed the intra-individual stability of the overall characteristics of the MRCPs. The pre-movement potential changes did not differ in separate parts of experiment. The mental movement simulation has modulated the parietal motion execution components. The pronounced change was observed in the first positive movement execution component, its amplitude being diminished at about 50 % ($p<0.01$). As for the first negative motion execution component, its latency being shorter under the movement simulation condition ($p<0.05$). Figure 2 illustrates the results.

Experiment 3

The mental imagery condition has brought about the significant increase of saccadic inaccuracy. The number of corrective saccades was significantly higher under this condition as compared to the control condition (30 %:5 %, $p<0.001$). The parietally recorded premotion positivity (preparation time for a saccade) was significantly shorter in control condition (50 % change, $p<0.01$). The spike potential (the maximal recruitment of the oculomotor muscle units at the saccadic onset) was delayed in imagery condition (20 % change, $p<0.02$). The frontally registered SEMRPs in imagery condition were found of longer duration (25 % change, $p<0.01$) and of earlier onset (70 % change, $p<0.01$) as compared to the control condition. The typical example is illustrated in Figure 3.

Discussion

The SEPs experiments have shown that the mental interference was registered over the both cortical areas. It was found out that the early frontal SEP components, which are generally assumed to represent coding the physical characteristic of the evoking stimulus, are under the influence of the interfering mental activity as well. It seems the early SEP components bear not only the sensory and motor processes but also the mental ones accompanying the planning and programming of the motor sequence. The fact, that mental activity with mental movement simulation affects the P20 component support the existence of a centrifugal gating (Jergelová et Podivinsky, 1994) as well as the assumption of Rossini et al. (1990) that the frontal component with a 30 ms latency reflects the modulatory effect of the activity in the cortico-subcortico-cortical loop involving supplementary motor area, premotor cortex, basal ganglia and the vetrolateral thalamic nuclei.

It can be speculated that the above mentioned centrifugal gating may prevent the influence of mental movement simulation upon the pre-movement potential changes of movement related cortical potentials. These pre-movement potential changes are sensitive to a variety of preparatory processes and represent a rather complex compound activity (Toro et al, 1993). The findings of unchanged pre-movement potentials under the mental movement simulation as compared to the control condition support the view that the preparation processes for both, the real movements and mentally simulated movements share probably some common neuronal mechanisms at the cortical level. It is in accordance with the hypothesis of a functional equivalence of motor imagery and motor preparation postulated by Jeannerod (1994).

Mental activity has influenced both the frontal and parietal saccadic eye movement related potentials, respectively. Again, the most pronounced changes were registered over the frontal areas. No differences were found in parietal correlate of primary encoding the visual stimulus (the so-called lambda wave). It means that the preparation and the onset of execution of saccades is influenced with a marked modulatory change over the frontal executive areas. Our previous results concerning the influence of the mental arithmetic on the accuracy of saccades and SEMRPs (Jagla et al, 1999) together with the above results point to a possible influence of the non-specific information processing within the specific visual and visuo-oculomotor neuronal loops elicited by ongoing mental activity. The mental imagery in the course of the visual fixation task distracts the attention from visual targets. The significantly higher number of corrective saccades could be taken as an evidence. It seems that to perform the visual fixation task when imagining a familiar face requires a certain engagement of memory.

The participation of working memory, focussing one's attention and voluntary control should be also taken into account in all the experiments. The SEPs, MRPSs and SEMRPs data support the traditional view that the frontal cortex is involved in the process of monitoring and manipulation of information that has been internally generated. Now, this function is attributed to the frontopolar prefrontal cortex (Christoff and Gabrieli, 2000). The prefrontal cortex is enormous association region which is connected through the cortico-cortical projections with all the neocortical areas and plays an important role in referencing stimuli to internal representations, directing attention appropriately, monitoring time sequence of events and other cognitive and executive functions (Rezai et al, 1993). The all above frontal changes are in relation to the internal representation, attention and sequence of events in time.

The frontal changes in first positive and negative execution components of MRCPs suggest the role played by focussing the attention upon the mental activity and distracting it from the proper execution of desired movements. Such an influence could be assumed in all the three experiments. The role of attention in the above conditions has to be studied in further experiments.

The results strongly suggest the need to specify exactly the experimental condition with instructions and to control the mental activity in the reference conditions as well. As it was shown, the mental activity can substantially modulate even those components of evoked potentials which are usually ascribed to physical characteristics of sensory stimuli.

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