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Estimation of Changes in Cerebral Cortex Functional State under Monotonous Operator Work

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Abstract—Comparative analysis of the N_{200} component of the evoked potentials in the frontal, central, parietal, and occipital cortical areas of the left hemisphere revealed dynamic changes in its amplitude dependence on the initial cortical activity and a degree of extraversion. Students mastering monotonous computer work, which required continuous concentration, participated in the experiments. In introvertive subjects with high initial cortical activity, the activity in fronto-occipital derivations predominated. On the contrary, in extrovertive subjects with a low level of initial cortical activity, task performance was accompanied by increased activity of the parietal area, which shifted to the frontal area with a fatigue increase. The findings obtained are indicative of individual and typologic features of adaptation to monotonous computer work.

The study of individual variability of brain mechanisms responsible for activity remains important due to new kinds of labor arising. A modern version of man–machine interaction is work on computers. At the moment, the computers are in wide use, but the problem of occupational fitness to this kind of work has been insufficiently studied. Thus research into individual and typological features of brain mechanisms ensuring long-term work on a computer is required. Studies of the operator's work demonstrated that adaptation to various kinds of labor depends on the constitutional features of the human body. The greater the inborn adaptive capabilities for certain work, the more easily one can succeed without being overstrained. In turn, adaptive abilities depend on different CNS parameters as well as the character and duration of the work [1, 2]. These and other factors pre-determine the integrative processes in the cerebral cortex necessary for the development of the optimal functional state, which can ensure high working efficiency. Essential factors determining the dynamic changes of the functional state (FS) of the cerebral cortex are personality characteristics and the genetically fixed level of general CNS excitability [3–6], including the initial level of cortical activity [7–11].

Changes in the cortical integrative system are realized through FS changes in individual cortical areas. The more the work fits the person, the less the initial integrative structure will be changed, and vice versa. The amplitude changes in the evoked potentials are very suitable for evaluating the dynamic changes in cortical FS.

The aim of this study was to comparatively evaluate the FS changes in different cortical areas under simulation of the monotonous operator work on a computer considering the individual background level of cortical activity, the degree of extroversion, and the working efficiency of the subjects in conditions of novelty and learning.

This study included assessment of amplitude changes of the N_{200} component of visual evoked potentials (EP)from the frontal, central, parietal, and occipital areas of the left hemisphere under involuntary and voluntary attention. In addition, the working efficiency was compared in two groups of subjects that differed in their initial cortical activation and in the degree of extraversion or introversion.

METHODS

Examinations were carried out on 52 male and female healthy right-handed students, aged 18 to 23 years who had no experience working with computers. The task performed by the subject simulated operator work at a statistics office for 4 h; it consisted of entering random data into the computer. Such a task requires long-term uniform performance and results in a state of monotony. The working efficiency was estimated by the computer counting the number of errors made by the subject during each hour of work. Before the experiments, personality features of the subjects were tested by the Eysenck Personality Inventory [13]. The subjects with an extroversion index below 12 were considered to be introverts, and those with an extroversion index above 12 were considered to be extroverts. Ambivertive subjects did not participate in the examinations. The background EEGs were recorded, and the initial level of cortical activity was determined according to Puister's classification [14] based on the α-rhythm power. In most of the students examined, the degree of extroversion correlated with the EEG pattern. In the introverts, the power of the background α-rhythm was higher than 1 V/s, whereas in extroverts

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it was lower. The subjects who did not demonstrate this correlation (15%) were excluded from the experiments. Two experimental groups were formed. The first group included 26 introvertive subjects with a high initial level of background cortical activity; the second group consisted of 18 extrovertive subjects with a low initial level of background cortical activity.

The experiments were carried out in a dark soundproof shielded room, where the subject was in a reclined posture, relaxed with eyes closed. The EEGs were recorded by a 8-channel Medicor electroencephalograph (Hungary). The experimental paradigm was controlled by a Mazovia minicomputer (Poland). An FTS-21 photic stimulator triggered by a selector unit of an ANIEG-81 analyzer–integrator was used to generate light stimuli. The stimuli were 50 μs light flashes of moderate intensity (0.4 J) spaced at intervals of about 3 s. The stimuli were presented under the conditions of involuntary and voluntary attention. In the first situation, the subject was instructed not to react to the stimuli. In the second situation, the subject was instructed to count the stimuli by simultaneously pressing a button (five different types of counting were used, with the same number of pressings in all experimental sessions).

The EPs were recorded by the standard electrodes located over four cortical areas of the left hemisphere: frontal, central, parietal, and occipital according to International 10–20 system. The reference electrode was on the earlobe. The potentials amplified by the electroencephalograph amplifiers (time constant 1 s, the bandwidth 0.5–70 Hz) were fed into an ADC connected to the computer.Thirty-two responses to the light flashes were averaged. An analysis epoch was 500 ms. In the averaged EPs, the amplitude of the N_{200} component was estimated. It was measured automatically with special software that allowed one to measure the peak amplitude within a strictly fixed time interval (180–210 ms). The data were analyzed statistically with Student's *t*-test.

Five recording sessions were carried out during the four-hour work with the monitor screen: before the work (T_0) and after the first, second, third, and fourth hour of work (T_1, T_2, T_3, and T_4, respectively).

Comparative evaluation of the FS of different cortical areas was performed by using significant maximal amplitude (MA) of the N_{200} component before the experiment and in the course of the four-hour work in both experimental conditions. Spatial distribution of the MA of the N_{200} component was presented topographically by means of computer graphics.

RESULTS AND DISCUSSION

In the first group prior to work (T_0), under the involuntary attention condition, the MA of the N_{200} component was revealed in the occipital region (figure, part a, *1*). The picture remained the same after 1 h of the work. After the second and third hours (T_2 and T_3), the MA was recorded in the parietal area. At the end of the experiment (T_4), the MA of N_{200} observed again in the occipital region. Thus, in the subjects with high cortical activity the exposure to light stimuli resulted in a natural increase of the FS in the occipital area.

In the subjects of the second group (figure, part b, *1*), there was no significant difference of the initial N_{200} amplitude values between different cortical areas in the situation of involuntary attention. In our opinion, this is indicative of synchronous work of the four cortical areas studied. After the first hour of work (T_1) and until the end of the work, the N_{200} amplitude was maximal over the parietal region.

Hence, for involuntary attention, the N_{200} amplitude was higher in the posterior cortical areas (occipital and parietal) in both groups. So, in the situation of involuntary attention the typology-dependent differences are not significant. As will be seen below, they arise in the situation of focused attention.

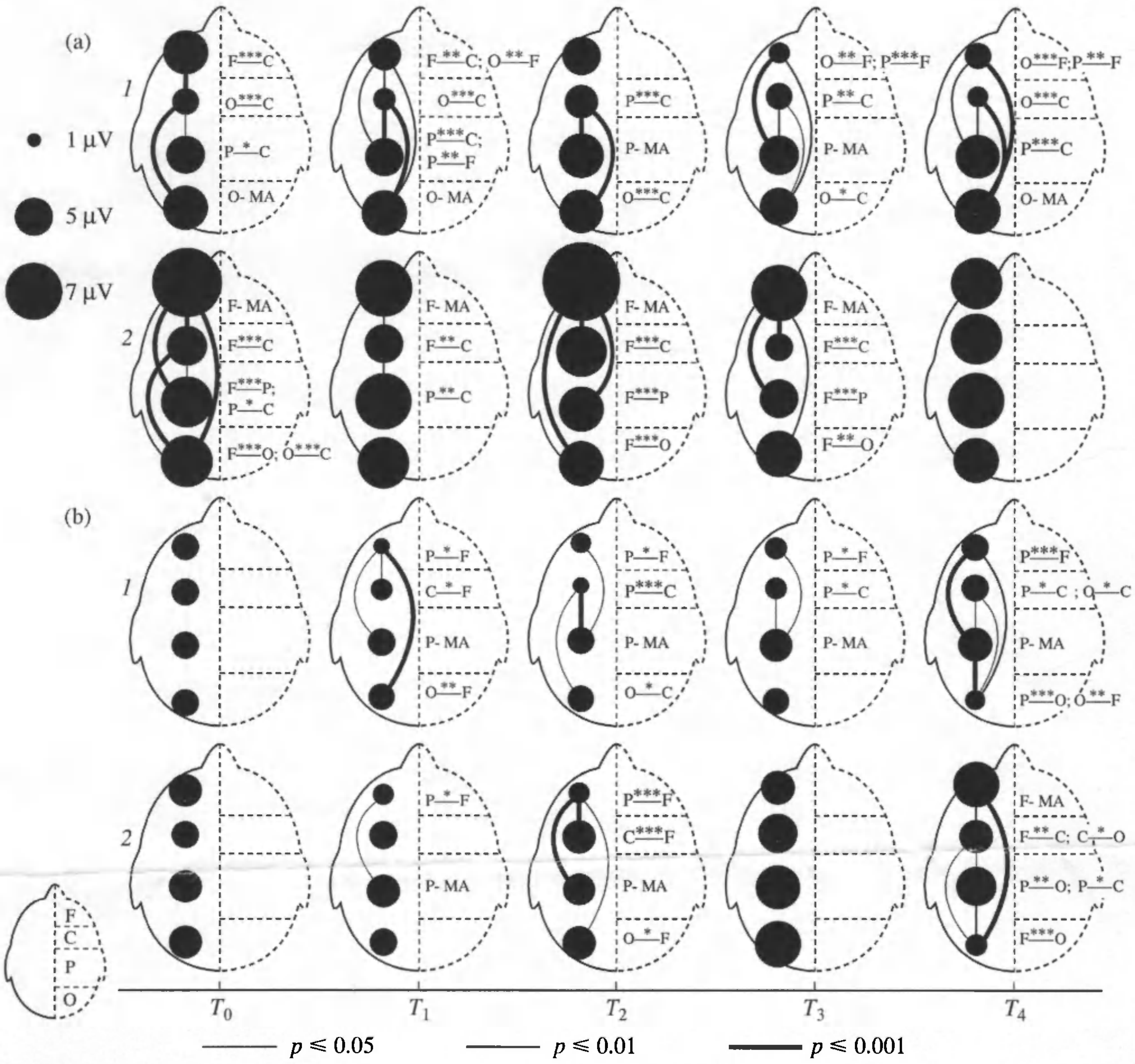
In the first group, attracting attention prior to the experiment resulted in the MA of the N_{200} component in the frontal cortical area dominating (figure, part a, *2*). This location remained stable during the whole experiment, with a significant MA of the N_{200} component increase observed at T_2. Thus, in the first group, increased attention was accompanied by an activation of the frontal cortex, which has strong descending connections with brain structures responsible for attention processes. It should be noted also that in this group, an increase in the FS level in the frontal cortex did not lead to a decrease in the occipital area: the absolute value of the N_{200} amplitude remained at the initial level.

In the second group, there were no changes due to voluntary attention (figure, part b, *2*). Over the course of this experiment (T_1, T_2, T_3), similar to the situation of involuntary attention, the MA of N_{200} we observed in the parietal area. Thus, attracting attention resulted in no changes in the dominant area. It was only by the end of the work (T_4) that the MA shifted to the frontal area, with a significant decrease in N_{200} amplitude in the occipital area.

Hence, in the subjects with low cortical activity, focusing attention and maintaining the optimal level of FS involved the parietal area. We believe, however, that the parietal area could not ensure the necessary cortical activity, and at the end of the work, fatigue processes resulted in the involvement of connections between the frontal cortex and subcortical brain structures.

The above data obtained in the experiments with monotonous work that constantly required focused attention allow us to assume that the adaptive abilities of the subjects in the first and second groups were different.

An analysis of working efficiency over the course of 4-h work showed that the task performance was almost equally successful in both groups. Most subjects of the first and second groups (83.3 and 75%, respectively) improved their performance by learning (the number of errors decreased) by the end of the work. This is indicative of acquiring a certain habit for the work. By the



Significant difference in spatial distribution of the MA of N_{200} component in the subjects of the first (a) and second (b) groups under involuntary (1) and voluntary (2) attention, prior to the work (T_0) and after 1, 2, 3, and 4 h of work (T_1, T_2, T_3, and T_4, respectively).

end of the work, some deterioration of the performance accuracy was noted in 8.4% of the subjects of the first and 17% of the subjects of the second group.

Thus, one can assume that the realization of attention processes underlying equally successful performance proceeds differently in subjects with different background cortical activity. The subjects of the first group in the condition of focused attention used the initial cooperation between the frontal and occipital areas, whereas the subjects of the second group realized their activity due to enhanced functioning of the parietal area.

CONCLUSION

Improvement of working efficiency during the 4-h work, i.e., successfully learning to work on a computer, can be realized by different brain strategies in persons with different CNS characteristics such as the background level of cortical activity, and the degree of extroversion.

In the introvertive subjects with high background cortical activity, an increase in the FS level in the frontal and occipital areas occurred over the whole learning period. In the extrovertive subjects with low cortical activity, the task was successfully fulfilled through an increase in FS in the parietal area. The between group differences in the cortical mechanisms responsible for the activity are indicative of the individual and typologic features of adaptive capacities during learning (monotonous work on a computer). The "forced" distortion of the usual integral pattern (which can result in the overstrain and deterioration of functioning of many cortical areas, especially the occipital area) in the extrovertive subjects with low background activity allow us to suggest that introvertive people with a high level of background activity are more capable in performing long monotonous work on a computer.

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