CHANGES OF ELECTRICAL REACTIVITY OF THE RIGHT AND LEFT CEREBRAL HEMISPHERES IN SCHOOL CHILDREN AFTER 5-6 HOURS MENTAL WORK

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G. N. Speranskii's study of cortical changes by the classical method of salivary conditioned reflexes has made it possible to reveal and describe prolonged inhibitory phases in the cerebral cortex of a child engaged in mental tasks, when there is a characteristic breakdown of the Pavlovian "law of strength" [7, 8].

An elaborate study of the relationships between cortex and subcortex in children engaged in mental tasks has been made by a study of conditioned reflexes and of the nonspecific autonomic components of conditioned and unconditioned reflexes; it has revealed inhibitory conditions not only at cortical but also at subcortical level [13]. It was found that the action of cold (+10°) on the receptors of the trigeminal nerve (skin of face) or stimulation of proprioceptors in the muscles (performance of a given amount of muscular work) during physical culture (gymnastics, basketball, or skiing) abolishes fatigue and the feeling of tiredness. The effect is to increase the tone of the subcortex and cortex; salivary reflexes are increased, they obey the "law of strength", and the autonomic components are considerably enhanced [13].

There is great interest in the EEG changes induced by rhythmical light stimulation. This method has made it possible to reveal an improvement in the synchronization processes during mental work by a child: there was an increase in the amplitude of the reactive cerebral potentials, and light flicker was followed better in the brain [9]. The objective treatment of the EEG by a modification of the method of Lowell and Dossett marked a great step forward. We have previously described this method and have given the results of a study of mental fatigue in school children [10, 12].

The details are as follows. For each frequency of the light flashes we prepared a transparent strip of tracing paper divided by points at equal intervals: a photocell was used to cause the points to produce marks on an EEG obtained in response to light stimulation. The strip of tracing paper was placed on the EEG record in such a way that the row of points coincided with the middle horizontal line of the oscillations. The strip was moved along the EEG trace until a maximum number of points fell outside the EEG oscillations (because the process was rhythmic; this shift did not exceed a half-period of the stimulus frequency). If a point lay on the outer line of a wave it was not counted. The coefficient of synchronization (K_s) was taken as the ratio of the number of coincident oscillations (P_c) to the number of applied light flashes (P_n), measured over a period of 10 sec; thus: $K_s = (P_c/P_n) \cdot 100\%$. All the oscillations of the EEG which coincided with the light flashes were measured by a strip of millimeter paper and their total length in millimeters was translated on the appropriate scale into microvolts and used as an index of the energy of the synchronized oscillations (ΣA_s). Determination of the simple quantities K_s and ΣA_s indicated the degree of reorganization of the cerebral electrical activity in response to the light stimulus (percentage assimilation), and indicated the number of nervous elements involved in the synchronization as shown by the amplitude of the oscillation in microvolts (ΣA_s) for a given frequency of stimulation. According to Lowell and Dossett* this treatment reveals a basic tendency to a change of the reactive potentials of the brain of a child fatigued by mental work. It is included

*E. L. Lowell and W. E. Dossett, Electrocortical Conditioning with Intermittent Photic Stimulation, manuscript, 1959.

in the quantity K_s, and particularly in ΣA_s. It is interesting to note that a block of the M-cholinergic and the adrenergic systems of synapses of the reticular formation of the brainstem by promazine, chlorpromazine, amizil, and metamizil caused the orienting reaction to be extinguished, increased the value of K_s, and brought about a greater increase of ΣA_s [14, 15].

The object of the present work has been to study the nature of the changes of electrical activity in the left and right hemispheres produced after 5-6 hr mental work by children aged 11 to 15 years.

We studied these changes in pupils of a boarding school before and after 5-6 hr study in class (the observations were made in G. N. Speranskii's laboratory between 1958 and 1961). From EEGs taken from 110 children we investigated 11 children aged 11-15; one child was studied twice, and another three times. We applied the method described above to 14 EEGs before and after the tasks. All the children were examined repeatedly by specialists, and were in good health; the daily routine was the same for all.

The question of the functional symmetry of the cerebral hemispheres was first studied objectively by I. P. Pavlov and his school [1-3, 5, 6, 11, 16], and was subsequently taken up by numerous investigators. We are specially concerned with changes in electrical activity of the brain occurring separately in the right and left cerebral hemispheres as a result of hard mental work, and its relation to the position on the left side of the speech center and the dominance of the left hemisphere. We have found no account of such an investigation. All that has been reported is that there is a dissimilarity in the electrical activity of the two sides, the α-rhythm having a more constant amplitude on the right side of a healthy human subject [20], and that the α-rhythm has a greater frequency and a lower amplitude in the left or dominant hemisphere, but this asymmetry may be expressed differently in different persons or in different parts of the cortex of one person [4]. We were directly interested in the asymmetry in the activities of the left and right hemispheres, as indicated by the motor response and its relationship to the degree of mental activity of the school child [17-20].

EEG records from the symmetrically placed occipital leads of the right and left hemispheres were examined in order to calculate K_s and ΣA_s, and revealed the following facts.

In the morning before work at about 8 A.M. the index K_s indicated an asymmetry in 8 of the 14 school children, and in five cases it was very marked. In seven cases of asymmetry K_s was greater on the left side.

In the morning, from the index ΣA_s asymmetry was indicated in 10 out of 14 experiments. In five cases it was marked. In eight cases the asymmetry as indicated by the index ΣA_s was greater on the left side. This result agrees with what was found by Corneil and Gastaut [21]; they applied photic stimulation to healthy persons, and found that when there was asymmetry the induced rhythm was taken up better on the left side where the amplitude of oscillations was greater.

After classwork the asymmetry as indicated by index K_s was found in 11 out of 14 experiments. In eight cases it was considerable. It is important to emphasize that after the work K_s was greater on the right side and not on the left. This change of increase of K_s occurred in seven experiments, and in four cases the value of K_s on the right was much greater than its value on the left.

After the mental task the index ΣA_s varied irregularly. The asymmetry was noted in as many as 13 out of 14 cases, in nine of which it was considerable. Then ΣA_s was not greater on the left as had been the case in the morning, but on the right (in 9 of the 13 observations). In five cases the shift in favor of the right side was considerable.

In most cases the changes in the left and right hemispheres were in the same direction, that is, toward an increase of synchronization with the light flashes.

Let us consider the case of L.S. aged 14 years, and examine the effect of six hours classwork on the responses of the right and left hemispheres (Figs. 1 and 2). The EEG of Fig. 1, a shows a trace of these potentials in the occipito-temporal lead on both sides at a frequency of stimulation of 13 cycles in a record taken in the morning before work. Mental work for six hours increased the degree of synchronization and the amplitude of the potentials induced (Fig. 1, b). The graphic analysis of Fig. 2 shows at a glance the increased asymmetry of the two sides. It is less well shown for the index K_s (Fig. 2, a) and is much more marked in the quantity ΣA_s. For the latter, at a stimulus frequency of 13 cycles the difference between the hemispheres was 3150 μv, and after six hours mental work ΣA_s on the right side was 4750 μv and on the left 1900 μv (Fig. 2, b).

The results we have quoted show that in most observations before mental work the brain of a child shows only a

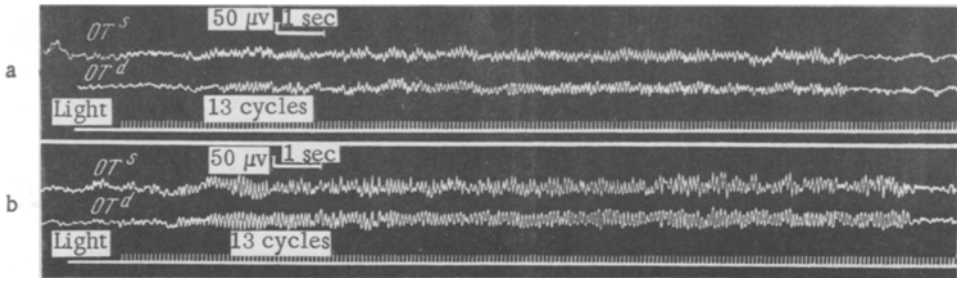

Fig. 1. Induced cerebral potentials; experiment of 6/V/1959 made in the subject L. S. aged 14 years (a) in the morning before work, and (b) after six hours mental work.

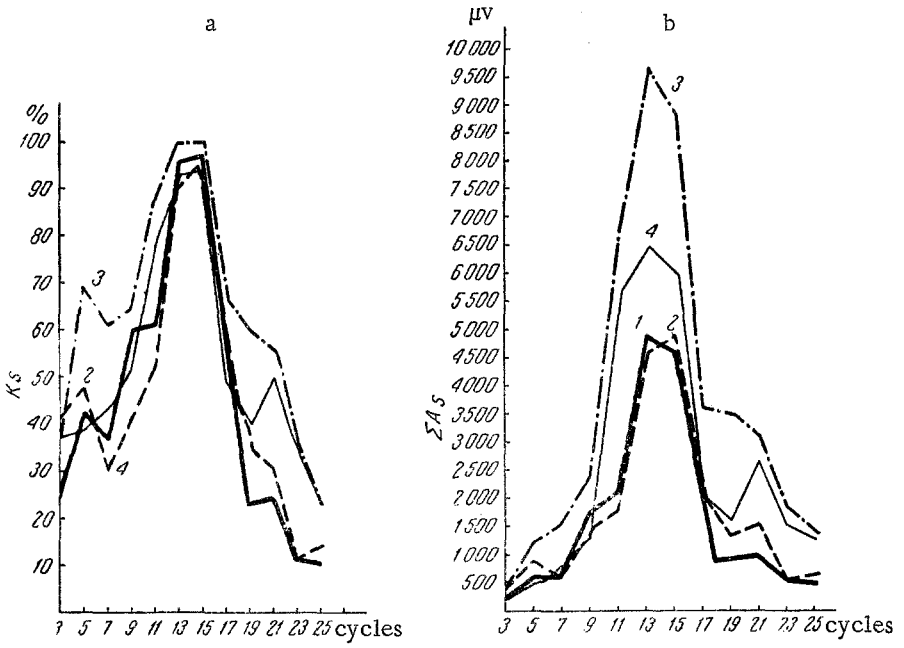

Fig. 2. Graphic analysis of (1) the right and (2) the left cerebral hemisphere before work; (3) the right and (4) the left hemisphere after six hours mental work in the subject L. S. a) Coefficient of synchronization (K_s) of the induced potentials; b) total energy of the synchronized potentials (ΣA_s) for each stimulus frequency.

moderate degree of electrical asymmetry between the left and right hemispheres. The two indices of synchronization (K_s and ΣA_s) are then somewhat greater on the left side.

After 5-6 hr mental work, when changes of excitability in the brain at cortical and subcortical level have been confirmed by conditioned reflex studies [7, 8, 13], the asymmetry in the synchronization has increased both quantitatively and qualitatively. Both indices of synchronization now show a greater value on the right instead of on the left. Also the asymmetry is much more clearly shown.

SUMMARY

A study was made in children aged 11-15 yr of the potentials induced in the right and left hemispheres before and after 5-6 hr of mental work in the classroom. The EEG was analyzed by a modification of Lowell and Dossett's method to determine the coefficient of synchronization (K_s) and the energy of the synchronized oscillations (ΣA_s) for each flash frequency. It appeared that, from these two indices in the majority of observations, a moderate asymmetry was present before the mental work was commenced, the indices being greater for the left hemisphere. After mental work when the brain was no longer optimally excitable, the asymmetry showed both a quantitative and qualitative increase. The values of the K_s and ΣA_s indices were now no longer greater on the left, but greater for the right hemisphere. We think that this change of synchronization is another aspect of the dynamic changes in the cortex which we have previously described as taking place after similar mental work in a comparable age group.

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