A POSSIBLE PRINCIPLE OF COMPENSATION OF KINESTHESIA

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In the modern view the kinesthetic analyzer (KA), part of the somatosensory afferent system, has bilateral projections to structures of the forebrain. Under these circumstances kinesthetic information from each limb reaches the cortex of the contralateral hemisphere via two systems of afferent fibers — the classical system, crossing at the level of the spinal cord and medulla, and the uncrossed ipsilateral connections, ascending from the limb in its own half of the brain stem, and reaching the cortical centers of the opposite hemisphere through brain commissures — the corpus callosum and the massa intermedia of the thalamus [3, 4]. Thus the development of our ideas on the somatosensory system and, in particular, somatosensory (kinesthetic) feedback during voluntary movements, insists that we regard KA as a system with multichannel organization, conducting the corresponding information about the position and movement of the limb to the cortex of the opposite hemisphere, along both crossed and uncrossed afferent pathways. Despite these views on the organization of KA, which were formed quite a long time ago, there are no publications in the literature which take into consideration its bilateral structure in the control system of the voluntary motor act.

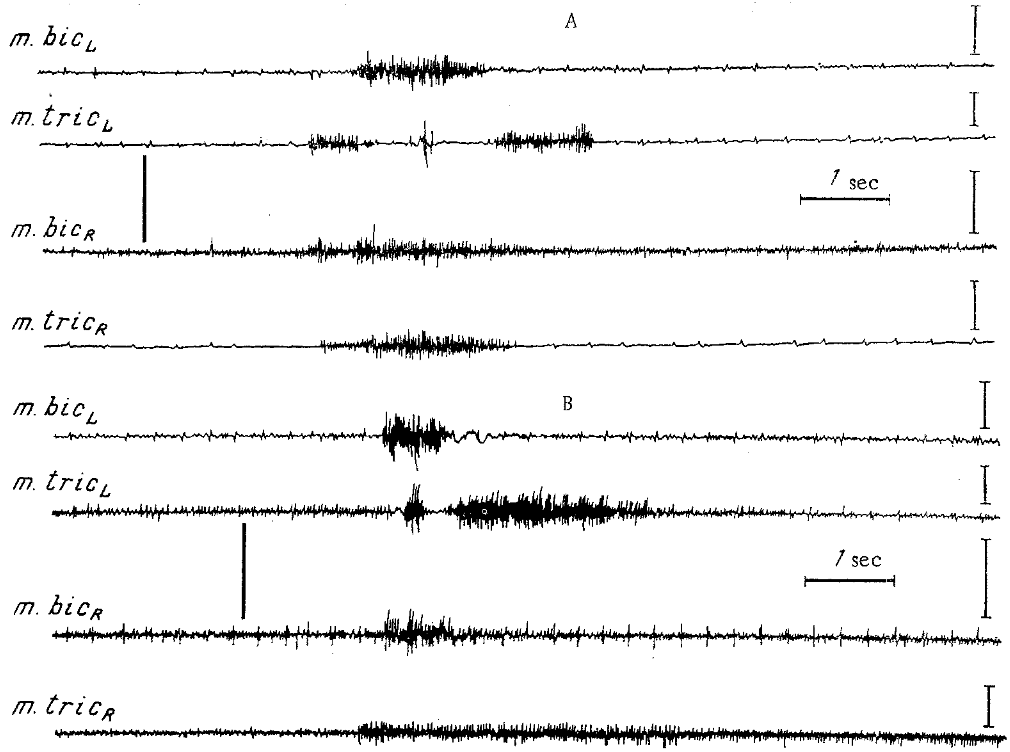

Fig. 1. Characteristic patterns of myographic activity during performance of skilled movement. A) Intact animals, B) deafferented animals. Top two traces show EMG of flexor and extensor of "working" limb, bottom two traces — the same for supporting limb. Vertical lines on left indicate time of application of conditioned stimulus. Horizontal lines on right: calibration 500 μ.

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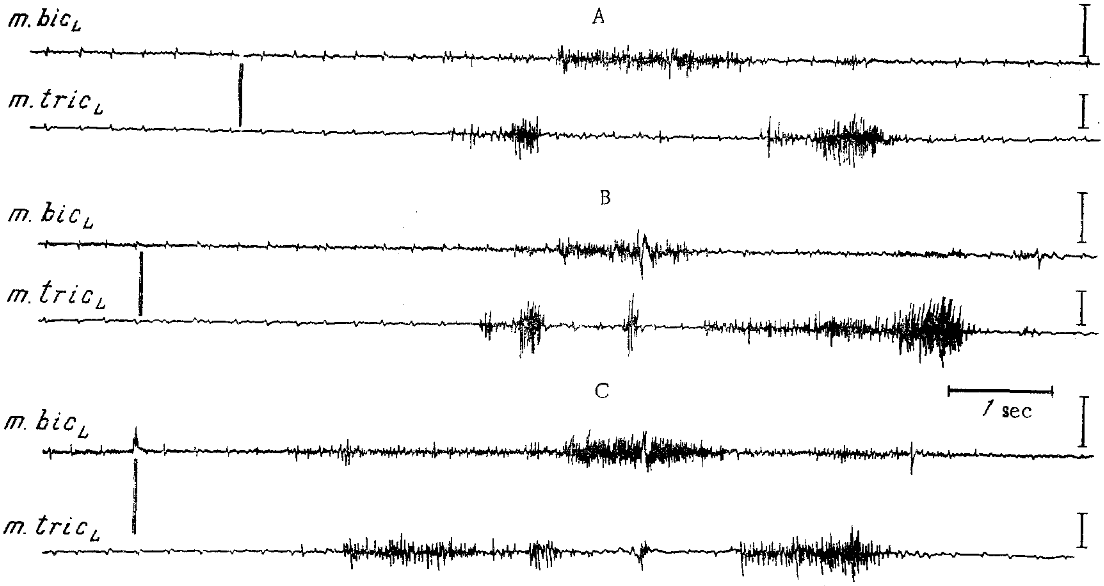

Fig. 2. EMG of three consecutive (A, B, C) responses by limb of intact animal. Remainder of legend as to Fig. 1.

With these considerations in mind the writer studied the same forelimb movement in intact animals (cats) and in animals in which only ipsilateral uncrossed channels for transmission of kinesthetic influences to the opposite hemisphere were preserved, as a result of neurosurgical division of half of the tegmentum mesencephali for the limb contralateral to the side of division.

EXPERIMENTAL METHOD

Experiments were carried out on 17 mature cats of both sexes, 12 of which underwent the operation, whereas five constituted the intact group. As a model of conditioned-reflex movement, the technique in [6] was used, with certain modifications. The animals were completely unrestrained, and were taught, while sitting on their hind limbs and resting on the forelimbs, to perform a smooth, easy, but clearly defined touching of a target presented by the experimenter, with the forelimb. Organization of the voluntary movement was assessed on the basis of the electromyogram (EMG) of the flexor and extensor msucles of the shoulder of both forelimbs mainly participating in the test movement. Electrodes of a special design [2] were used for chronic recording of the EMG, and were implanted into the muscles indicated above, while the leads were taken subcutaneously and fixed to a socket secured to the animal's skull. The recording apparatus used in the experiments was standard.

EXPERIMENTAL RESULTS

Analysis of the myographic characteristics of the voluntary motor act showed that the pattern of muscular activity observed most frequently (about 80%) in intact animals consists of three clearly demarcated phases (Fig. 1A): isolated activity of the antagonist, subsequent activity of the agonist and, finally, a final burst of the antagonist. In the overwhelming majority of cases, against the background of isolated action of the flexor, single activity of the extensor reflecting direct touching of the target was observed. The supporting activity was characterized by simultaneous activity in both antagonist muscles, which was more marked in the extensor. The beginning of the response of the supporting limb coincided with the beginning of muscular activity of the moving limb. On the whole, the general pattern was of the "finished" type and was characterized by marked weakening of muscular activity, which continued until presentation of the next conditions stimulus.

In animals deafferented with respect to lemniscal influences, performance of the same motor act was characterized by a different myographic pattern (Fig. 1B). In this model situation the commonest pattern (about 74%) of conditioned response differed from the muscular mosaic of intact animals by the absence of the initial phase of extensor activity, and also by the well-marked synergic activity of the antagonists. Disturbance of reciprocity and the appearance of synergism in animals with different deafferentations are observed both during

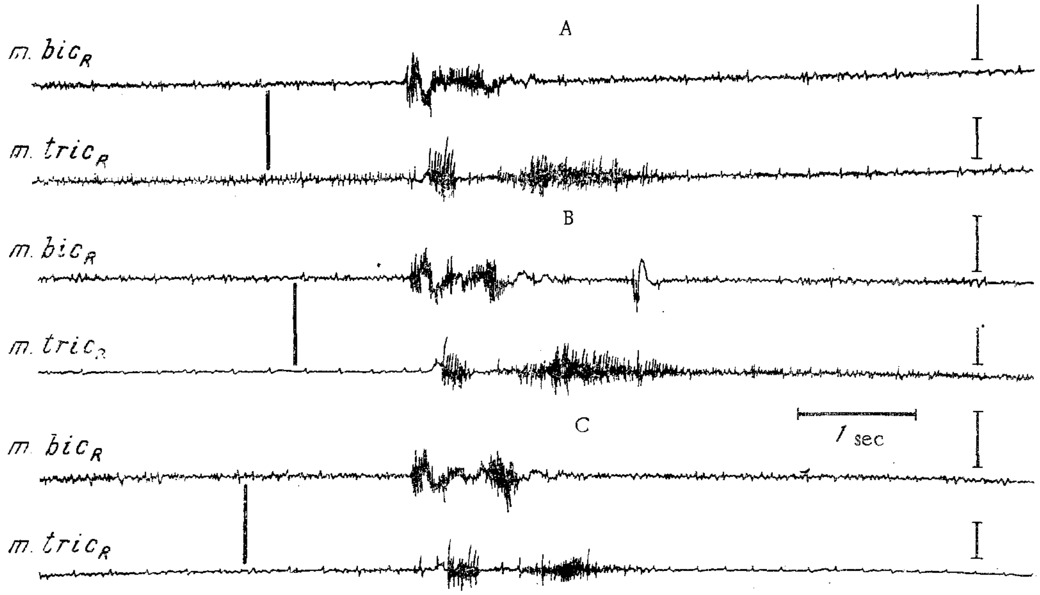

Fig. 3. EMG of three consecutive (A, B, C) responses by "working" limb of deafferented animals. Remainder of legend as to Fig. 1.

walking [8] and during performance of a certain task of movements [1]. Just as in intact animals, the movement ended with concluding activity of the antagonist. The muscular pattern of the supporting limb was characterized by brief activity of the flexor and prolonged tonic activity of the extensor, whereas in intact animals the opposite relationships were observed. It must also be noted that activity of muscles of the supporting limb preceded that of the working limb, i.e., adoption of the initial posture before movement by the deafferented limb required greater participation of the opposite limb than normally.

Finally, another sharp difference in performance of the motor skill by animals of the two experimental groups was a significant difference in the temporal parameters of the conditioned response. For instance, whereas in intact animals, despite no change in the general coordination pattern, the temperal parameters of its individual components varied widely among each other (Fig. 2), in deafferented animals variation of the temporal relations gave way to their stabilization. On the whole the mosaic of movements in these animals was impoverished and the patterns of muscular activity differed very litte from one another, but exhibited motor stereotypy (Fig. 3). For example, the duration of activity of the flexor of the working limb in the intact animals averaged 1.41 sec, with a dispersion of 0.30 sec, whereas the same parameter in the deafferented animals was reduced by more than one-third, to 0.91 sec. Its scatter also was significantly less, namely 0.18 sec (F test, P = 0.05).

Interruption of the classical lemniscal projections of KA, while not preventing the animal from controlling the corresponding limb, led at the same time to significant changes in performance of the conditioned-reflex skill, i.e., disturbs the system controlling the voluntary motor act. Under these circumstances the pattern of movements was impoverished and was characterized by motor stereotypy. Previous observations on animals undergoing the operation on the midbrain suggested that ipsilateral (extralemniscal) and commissural channels of KA can largely compensate for a deficit of kinesthetic influences arising as the result of division of the medial lemniscus [4, 5]. However, analysis of organization of the motor act in such animals, by a sensitive myographic technique, yielded a new and important conclusion in addition to these observations.

We know that control of the voluntary motor act by the CNS can be effected in two ways: by circular control, when the movement is corrected in the course of its performance, and by a programmed method, through the realization of ready-made motor programs, which can no longer be modified during their performance. This type of control, which predominates in lower animals, in which relationships between the sensory input and motor output are rigid, in higher animals and in man is observed mainly during rapid movements and movements based on inborn coordinations [1].

It can be concluded from analysis of these results that a deficit in kinesthetic information arising because of exclusion of powerful lemniscal projections from the feedback system, is compensated not only on account of ipsilateral connections of KA which remain intact, but also through switching of the nervous sytem to a different level of control of the voluntary motor act, which itself requires weaker participation of somatosensory feedback, namely feedback exerted on a centrally programmed level of control. Extralemniscal projections of KA under these circumstances can form and correct this program, and can also provide afferentation from the effect. By developing and widening these views, we can take a general look at the process of compensation in the CNS from certain novel standpoints. What do we understand by this process? Traditional ideas regard it as a process of activation of nervous formations or conduction systems not previously involved in the realization of a particular function, or activation, as we might say, of the reserves of the brain. At the same time, however, another principle may be involved, namely the switching to a different level of control of nervous structures and connections which previously had been concerned in the realization of that particular function, i.e., what we indeed can observe in compensation of processes controlling motor activity may also take place in any other compensatory reorganization of the nervous system. Views similar to these have also been expressed in [7].

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EFFECT OF TAURINE ON Ca,Mg-ATPase ACTIVITY AND PLATELET AGGREGATION IN MAN

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The role of calcium ions in realization of the dynamic properties of platelets is currently receiving considerable attention. Functioning of the contractile system of platelets, triggering the reaction of their release, prostaglandin synthesis, and regulation of the cyclic nucleotide system — these processes determining the level of platelet aggregating activity, changes in which are associated in turn with the pathogenesis of several hematologic and cardiovascular diseases and syndromes, are all connected with mobilization of intracellular calcium. Calcium metabolism in platelets, compared with its metabolism in cells of the myocardium and striated muscle tissue, has received less study. However, there are indications that factors in the regulation of calcium metabolism in excitable cells, such as the ATP-dependent transport system, Ca-binding proteins, and so on, actively function in platelets also [9].

The sulfoamino acid taurine is considered to be an effector of calcium metabolism in excitable tissues [1, 10]. It has also been found that platelets constitute a unique depot of taurine in the blood, for its concentration in them is 400 times higher than in plasma [4]. Taurine was shown previously to have an activating effect on energy-dependent calcium transport in excitable cells and it has been suggested that this is a universal effect for cells of different types [1, 2].

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