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ROLE OF THE *CORPUS CALLOSUM*

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TRĄBKA J.: *Role of the Corpus Callosum*. Acta Physiol. Polon. 19 (1): 1—10, 1968. — The present study deals with the precise determination of the callosal connections between the cerebral hemispheres applying the technique of chemical stimulation of homonymous cortical areas, as well as of surgical transection of *corpus callosum*. The association areas (lateral gyrus) and the primary auditory areas in the cat brain were chosen for experimentation in respect to great abundance of their callosal interconnections. Experiments were performed on 20 cats under chloralose and barbiturate anesthesia. The method of producing the evoked responses and the recording-stimulating device principle have been described in earlier papers. Transection of the *corpus callosum* inhibited the so-called "callosal effect" but did not abolish the contralateral concomitant response. In animals under chloralose anesthesia with transected *corpus callosum* extra-contact interhemispheral connection was possible. No such connection was observed under barbiturate anesthesia.

In the previous paper [14] the effect of chemical agents applied on the cortex on the response evoked in the cortical area symmetric to the site of chemical stimulation has been demonstrated. It could not, however, be established whether this influence is transmitted through the *corpus callosum* or by a roundabout way by the mediation of subcortical retransmission stations.

The present work is an attempt at determining more precisely the interhemispheral relations with the use of the technique of chemical stimulation applied on the cortex of homonymous cortical areas and of surgical transection of the *corpus callosum*.

If we assume that the influence of the functional state of one area on the contralaterally symmetric one may pass accross the median line at a higher *(corpus callosum)* or lower level of subcortical centers of the brain stem, it may be possible to establish which components of the evoked and concomitant responses, and in what degree depend on the changes of the functional state of the symmetric cortical area or on other extracortical influences.

For the studies the association areas *(lateral gyrus)* and the primary auditory areas in the cat brain (ectosylvian middle gyrus) were chosen in view of the great abundance of their callosal interconnections [1, 3].

An electric stimulus unilaterally applied to the sciatic nerve evokes bilateral cortical responses in the association areas. According to *Bremer* [3], the nervous impulses arising on stimulation of any segment of the afferent pathway reach first the first order projection area, from which they are secondarily transmitted to the cortical association area, this becoming manifest in the form of what is known as evoked association response. In the association area in turn, the impulses are further retransmitted by the *corpus callosum* fibres of the homonymous site of the association area, eliciting with a certain delay what is known as the concomitant response.

The relations between homonymous cortical sites of the hemispheres are not limited to an unidirectional influence only. It results from the studies of *Marsan* and *Laskowski* and *Chatrian et al.* that at the base of what is known as the commissural effect, there lie two-directional relations between the symmetric cortical areas.

The cooperation of homologous cortical sites takes place *via* short homonymous callosal pathways and *via* long multineuronal circuits closed within the area of subcortical brain stem centres. The paper by *Rutledge* and *Kennedy* in which the authors describe what is called interhemispheral delayed responses, indicates the existence of an interhemispheral extracommissural system.

The participation of extracortical influences, i. e. afferent impulses transmitted to the cerebral cortex by noncrossed homolateral pathways, in the concomitant response is also possible.

METHODS

The experiments were made with 20 cats of both sexes weighing 2·5—3·2 kg. In ten animals the *corpus callosum* was stereotaxically transected by the method of *Magni et al.* The experiment comprised two steps: in the first, after inducing amytal (40 mg/kg) anesthesia, three holes were bored in the skullcap along the sagittal line at a 2-mm distance, through which a silver wire was passed infradurally. The anterior and posterior holes were widened towards the median line, then the wire was shifted to the median plain of the brain. Into the openings with coordinates: for the anterior one A = 21·5; L = 0; posterior one A = 3; L = 0, needles were inserted through the eyes of which the ends of the wires were passed. Section of the *corpus callosum* was achieved by introducing simultaneously the anterior and posterior needle to a depth H = 1·5 and 4·5, respectively. In six cases the transection was complete and in the median line (Fig. 1), and in four cases the plane of section impaired the medial surface of the cerebral hemisphere and the transection of the *corpus callosum* was incomplete. The nontransected parts, the *genu* and the posterior pole of the callosal body were of no account in the evaluation of the results, since the fibers connecting the association cortex and auditory projection areas are localized in the middle part of the *corpus callosum*. Two to four weeks after transection of the *corpus callosum* the animals were used for the experiment proper.

Six cats with sectioned *corpus callosum* were subjected to chloralose (80 mg/kg), and the four remaining ones to barbiturate (40 mg/kg) anesthesia. Similar conditions were applied to the control group of ten cats. The experimental procedure is shown by the scheme in Fig. 2. Chemical stimulation consisted in placing on the cortex for

Fig. 1.

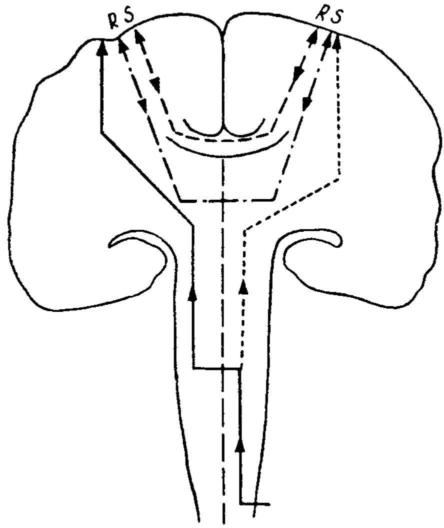

Fig. 2.

Fig. 1. Preparation with transected *corpus callosum*.
Fig. 2. Scheme of experimental situation for evoked association responses. R and S sites of chemical stimulation and recording. Dashed line denotes callosal pathway, dash-dot — extracallosal connections, continuous line — crossed sensory pathway, dots — sensory noncrossed pathway.

a period of 2—5 min a piece of filter paper (2×2 mm) impregnated with a 10^{-4} g/ml LSD solution (Lysid Roche) and 1-methyl-methoxy-1,2,3,4-tetrahydrocarboline (MTHK) 10^{-4} g/ml. The one-synaptic pathway of the transcallosal system proved to be particularly sensitive to the inhibitory action of LSD consisting in a reduction of the amplitude of the evoked callosal responses. The similarity of the pharmacodynamic effects of LSD and MTHK on the central nervous system was proved by the EEG and the changes in the behavior of the animals [13]. Moreover, MTHK similarly as LSD had a depressor action, blocking the evoked association responses [15]. Chemical stimulation was performed alternately: according to the side on which the sciatic nerve or the *foramen rotundum* was stimulated and on the contralateral side. The responses evoked were led bilaterally in symmetric areas by means of silver ball electrodes by the unipolar method. The reference electrode was implanted into the edge of the skin incision. The way of producing both the types of evoked responses and the recording-stimulating apparatus used have been described in earlier papers [11, 15].

RESULTS

Administration of LSD and MHTK on to the cortex in the association area of the cat brain with intact *corpus callosum* reduced the amplitude of the individual evoked responses, prolonged their latency period and

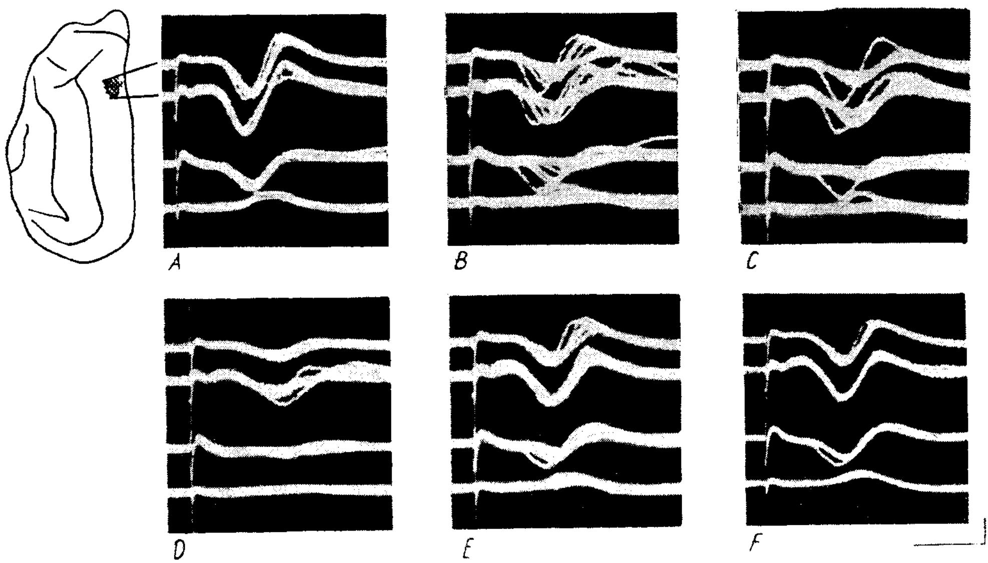

Fig. 3. Cat No. 13 with unsectioned *corpus callosum*. Effect of MTHK administration on left association cortex response (site of application marked on scheme). Stimulation of right sciatic nerve. A — before administration, B — immediately after application, C, D, E and F — 2, 5, 15 and 25 min after application. Level line marks 20 msec, vertical line — 200 μV, (the same notations are used in the following figures).

caused a complete flattening both on the side on which chemical stimulation was applied and in the homonymous area of the other hemisphere. A typical course of changes after chemical stimulation is shown in Fig. 3.

Simultaneously with the disappearance and delay of the negative waves on the left side (i. e. on the side of chemical stimulation and contralateral to the side of right sciatic nerve stimulation) there occurred changes in the evoked responses in the right association area. In the period of the maximum effect (5 min after removing the chemical agent), on the side contralateral to the site of stimulation, the evoked response was completely abolished, whereas at the site of chemical stimulation the positive wave persisted only partially blocked.

Transection of the *corpus callosum* did not abolish the contralateral concomitant responses which, moreover, showed no changes that could allow to distinguish them from those obtained in animals with intact *corpus callosum.* Only in one case (Fig. 4) was a delay of the concomitant response exceeding 1·8 msec observed as compared with the left-side association response. MHTK administration between the leading electrodes

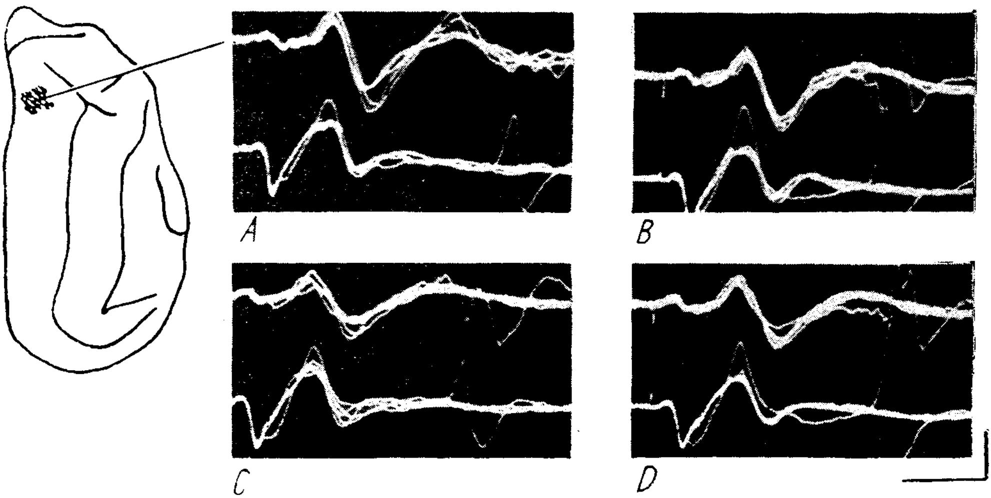

Fig. 4. Cat No. 1 with transected *corpus callosum.* Effect of LSD on right association cortex at site hatched on scheme. A — before administration, B, C and D — 2, 5 and 15 min after administration.

caused changes in the pattern of the concomitant responses but did not influence the contralateral evoked response.

In the preparation with sectioned *corpus callosum,* chemical stimulation with blocking compounds, irrespective of the side stimulated, did not as a rule affect the response evoked in the symmetric cortical area of the other hemisphere. Transection of the *corpus callosum* thus abolished the combined influence of chemical compounds referred to as the callosal effect (Fig. 5).

The situation was analogous to that in the auditory analyzer in which after transection of the *corpus callosum* no combined effect of chemical stimulation was observed.

On the side chemically stimulated the primary auditory response was transformed (chiefly in the areas of surface-negative response), whereas the contralateral concomitant response remained unchanged (Fig. 6).

The case shown in Fig. 7 in which LSD administration on the left-side cortex (opposite to the stimulated nerve) caused a bilateral block of evoked responses was an exception.

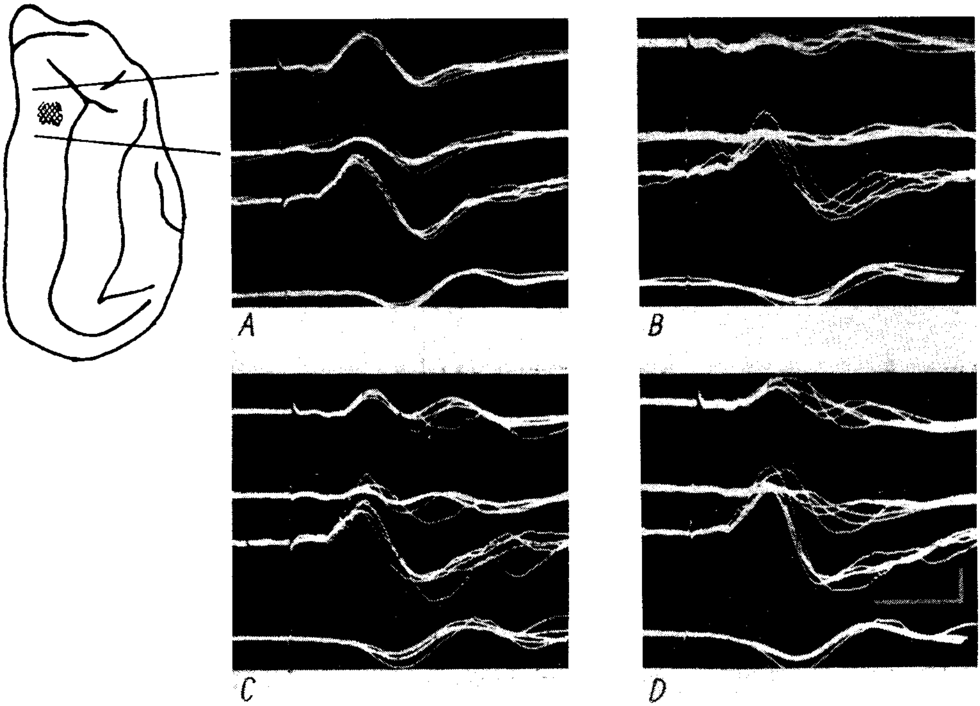

Fig. 5. Cat No. 13 with transected *corpus callosum*. Effect of MTHK on right association cortex at site hatched on scheme. A — before administration, B, C and D — 5, 15 and 25 min after administration.

This effect of coupled blocking of evoked responses in animals with transectioned *corpus callosum* was not observed under barbiturate anesthesia.

DISCUSSION

The role of the *corpus callosum* has not been completely elucidated. According to *Bremer* and *Stoupel* [3], the callosal mechanism ensures transmission of the stimulating or inhibitory influence from one hemisphere to the homonymous cortical area of the other. The joint action of the symmetrical contralateral cortical sites is manifested, as these authors believe, by a synchronization of the bioelectric potential, which disappears after section of the *corpus callosum*.

It results from the studies of *Myers* and *Sperry* that the memory traces in the process of learning are transmitted through the *corpus callosum*.

The two-directional influences crossing the median line along the callosal fibers are not identical on both sides and do not consist in a simple exchange of stimulations, owing to which identical copies of the picture of the "reflected world" arise in the homonymous cortical areas. At the basis of what is known as cross-integration there lies — according to *Sperry* — the principle of "accessory supplementation". Impulses from one hemisphere transmitting additional information about the picture,

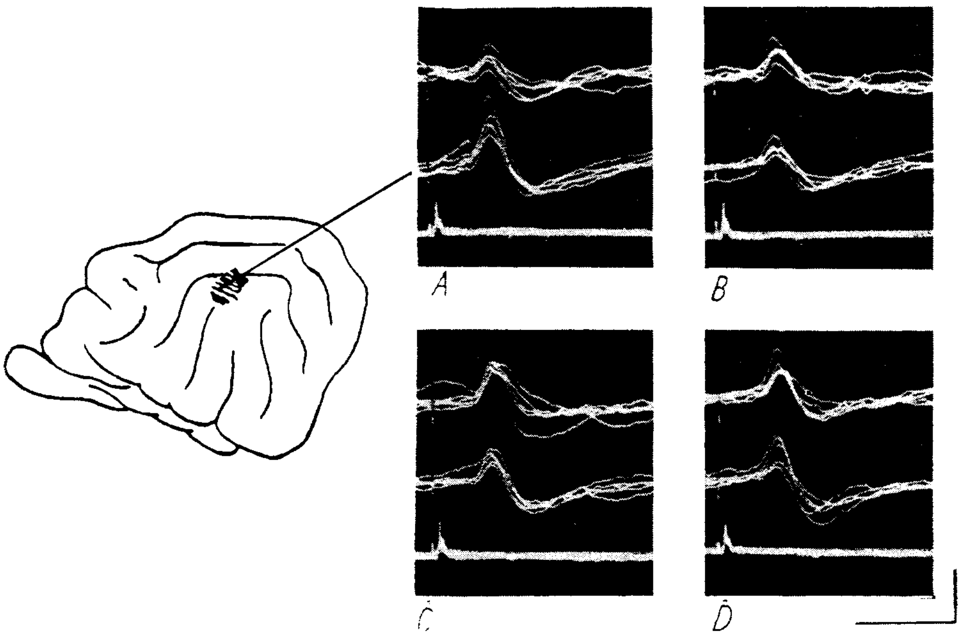

Fig. 6. Cat No. 5 with transected *corpus callosum*. Effect of LSD on left primary auditory response. Area of chemical stimulation hatched. Acoustic stimulus applied on right ear. Action potentials from right foramen ovale are led from the 3rd channel from below. A — before administration, B, C and D — 5, 10 and 15 min after administration. Level line marks 15 msec, vertical line — 200 μV.

the main reflection of which is found in the other hemisphere, travel to the the homonymous point of the other hemisphere.

In the cortical projection and association areas among others three kinds of fibers converge: one transmits impulses from the neighboring symmetric cortical area by the shorter one-synaptic path, whereas the others — by a longer way leading through the brain stem structures. The third route probably leads along uncrossed fibers transmitting influences from lower centers, not by the mediation of the cortical center in the other hemisphere.

The contribution of the three efferent circuits to the formation of the evoked response varies. Elimination of the callosal mechanism does not affect the contralateral concomitant response, but it abolishes the contralateral action of the chemical compound. Blocking of evoked responses or a change in their shape on one side does not necessarily cause corresponding changes on the opposite side. In preparations with sectioned *corpus callosum*, the combined action called the callosal effect is, therefore, not observed.

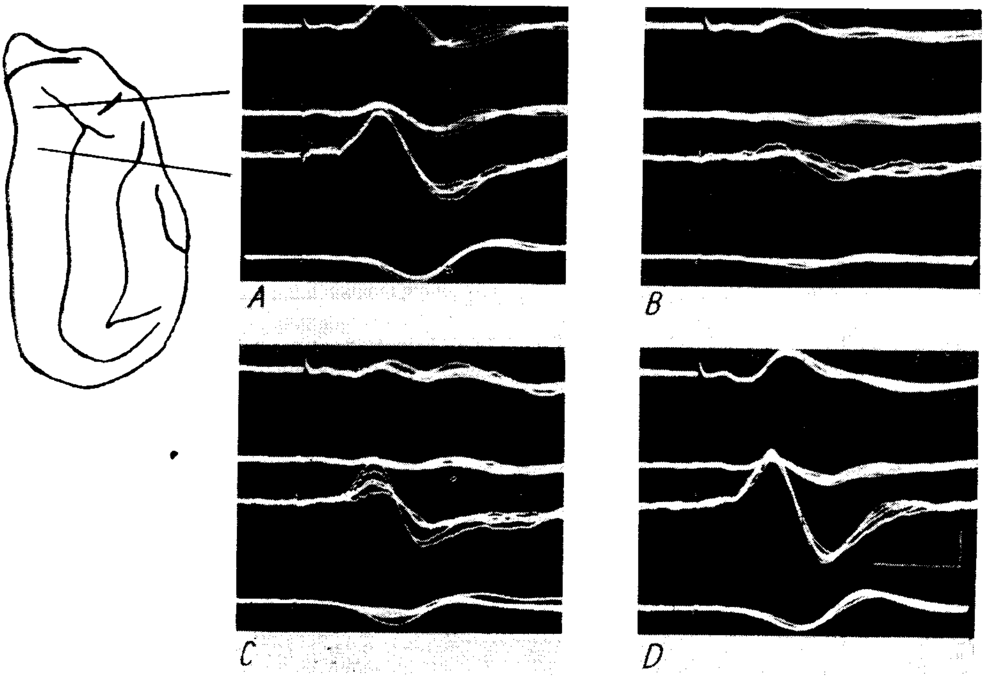

Fig. 7. Cat No. 13 with transected *corpus callosum*. In scheme the position of the recording electrodes is marked. A — before administration, B, C and D — 5, 10 and 15 min after administration.

In most of the experiments performed the longer multineural pathway crossing the median line at the level of the brain stem could not take over the function of transmitting the influence of supracortical chemical stimulation. Nevertheless, the possibility of this lower intrahemispheral connection did not cease to exist. This could be concluded from some, not numerous, experiments made with animals under chloralose anesthesia. On the other hand, under barbiturate anesthesia, the pathway with synapsis probably within the reticular formation never came into activity.

The interhemispheral influences transmitted two-directionally in the *corpus callosum* do not counterbalance each other, as proved by the dependence of the chemical stimulation from the side on which the sensory pathway is stimulated when the chemical compound is applied on the cortex. Chemical stimulation applied on the side opposite to the site of stimulation of the sciatic nerve or the *foramen ovale* was more effective.

It may be concluded from the experiments discussed that the callosal fibers play an important part by ensuring synergism in the function of the symmetric cortical areas. The callosal mechanism in some exceptional cases may be substituted by the interhemispheral connection system at the brain stem level. This possibility may explain in some extent why cases of symptomless congenital absence, or of operative damage to the *corpus callosum* are found in clinical practice.

Bremer [1, 2] and *Purpura* and *Girodo* when applying electric stimulation to symmetric cortical sites reached similar conclusions as regards the intrahemispheral connections. The differences between the effects of electric and chemical stimulation, as applied in the course of investigations on the problems concerning the *corpus callosum,* will be the subject of a further paper.

CONCLUSIONS

1. Transection of the *corpus callosum* abolishes what is known as the callosal effect, but does not abolish the contralateral concomitant response.
2. Under chloralose anesthesia a postsynaptic interhemispheral connection was possible in animals with sectioned *corpus callosum.* No such connection was observed under barbiturate anesthesia.

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