RECOVERY OF EMOTIONAL BEHAVIOR AFTER LESIONS OF THE SEPTAL AREA

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Abstract. Temporary decortication induced by acute cerebral ischemia or insulin coma reinstated the initial syndrome of emotional hyperreactivity in rats fully recovered from septal forebrain lesions. The effect was virtually the same as observed earlier with the use of spreading cortical depression. Surprisingly it was found that insulin coma induced during the acute phase of the septal syndrome but not after regression facilitated the recovery of normal emotional behavior. It is postulated that the observed effects of temporary decortication do not result from transient abolition of cerebral functions but rather from the disorganizing action of functional decortication, which consists of disruption of old and freshly formed neural connections.

In the studies of Teitelbaum and myself (6, 7, 16) the cortical spreading depression of Leão (12), induced by potassium chloride applied directly to the dura in rats with prior subcortical damage, reinstated the original syndrome even in fully recovered animals. Virtually identical effects were obtained with all syndromes resulting from subcortical lesions produced. Animals that had recovered from lateral hypothalamic lesions (6, 16) displayed severe disturbances in food and water intake, including total aphagia and adipsia, and only intragastric tube-feeding could keep them alive. Animals no longer exhibiting signs of anterior hypothalamic lesions (6) again showed thermoregulatory impairment, and rats recovered from septal forebrain lesions (6, 7) manifested a reinstatement of the syndrome of septal hyperemotionality. The last of these studies was the starting point of a series of experiments, carried out
with several co-workers, concerning the problem of recovery of emotional behavior after damage to the septal forebrain region.

Although sporadic reports on emotional changes induced by lesions of the forebrain in the vicinity of septum had appeared (8, 15), a detailed description of the septal syndrome was given for the first time by Brady and Nauta (3, 4). This syndrome consists of a great enhancement of emotional reactivity in animals with septal lesions. The syndrome is well-defined and relatively short-lasting because emotional reactivity steadily returns to its normal level within 2 to 3 weeks. Also, its symptoms are obvious, and their intensity can be measured with the use of relatively simple rating scale. For these reasons and the fact that the animals; apart from their aggressiveness, are not troublesome and can be easily maintained, the septal syndrome is one of the most convenient for studies on the recovery of function in the central nervous system. Thus, it was used in all experiments presented in this paper.

Figure 1 shows the effect of septal lesions on emotional reactivity in rats. The experiments were carried out on 14 animals randomly divided into two equal experimental and control groups. The experimental group was subjected to stereotaxically guided electrolytic lesions in the septal forebrain region, while the control group remained without surgery. Then, both groups were scored daily for their emotional reactivity according to the rating scale proposed by Brady and Nauta (3, 4) and

![Graph showing the effect of septal lesions on emotional reactivity.](Image)
described in detail elsewhere (7). The intensity of reaction for seven components of emotional behavior, such as reaction to handling, vocalization upon capture, reaction to prodding the snout and legs with forceps, etc., was scored and expressed numerically with the use of a 0- to 3-point rating scale.

As shown in Fig. 1, emotional reactivity, which markedly increased after damage to the septal region, steadily returned to its normal level within 3 weeks. Then, bilateral cortical spreading depression was instituted in both groups. As shown in Fig. 2, during the first 10 hr com-

Fig. 2. Effect of cortical spreading depression on emotional reactivity in rats fully recovered from septal syndrome. Denotations as in Fig. 1. From J. Cytawa and P. Teitelbaum (7).

plete reinstatement of septal symptoms was observed in the experimental group. Emotional reactivity was heightened for many successive days. It gradually decreased, eventually reaching its normal level on about the 12th day. During the same time in the control animals the effect of cortical spreading depression was negligible and almost imperceptible.

These experiments show that the cerebral cortex plays an active role in the process of recovery of function. Temporary decortication induced by cortical spreading depression abolished the recovery and reinstated the symptoms previously seen. It is worth mentioning that the role of the cerebral cortex in the recovery of emotional behavior was also evident in the experiments of Yutzey, Meyer and Meyer (19), who found that septal symptoms did not disappear spontaneously in rats with concomitant septal and neocortical ablations.

To check whether these effects truly resulted from abolition of func-
tion of the cerebral cortex or from general anesthesia induced in animals which nervous system had been sensitized by prior cerebral damage, the effect of 3-hr ether anesthesia on emotional reactivity of recovered septal animals was then investigated (Fig. 3). Emotional reactivity was tested according to the same rating scale, but in this Figure, as well as in all that follow, it is expressed in per cent of the norm, with the whole range of scores obtained before the septal lesion in each rat taken as

![Graph showing emotional reactivity](image)

Fig. 3. Effect of ether anesthesia, applied after recovery from septal syndrome, on emotional reactivity (median ± quartile deviation; n = 6). All explanations in text.

100%. When emotional reactivity increased, the percentages were calculated in relation to the highest normal results, whereas, when it decreased — to the lowest normal results. Figure 3 shows the effect of septal lesions on emotional reactivity within the first 6 days following the operation and after recovery from the septal syndrome in the days just preceding and following the application of ether anesthesia. The duration of 3-hr anesthesia was comparable with that of cortical spreading depression. As shown in Fig. 3 this procedure did not exert any influence on recovered septal animals.

In a subsequent experiment the influence of acute cerebral ischemia produced by bilateral occlusion of the common carotid arteries for a period
of 1.5 min was examined (Fig. 4). It follows from the studies of Baldwin and Soltysik (1, 2), carried out on goats, that such ischemia induced temporary abolition of brain bioelectrical activity without permanent damage though in these animals almost the entire brain is vascularized by branches of the carotid arteries. As in the case of cortical spreading depression, cerebral ischemia reinstated the septal syndrome in animals which had fully recovered from septal lesions. This effect, though small, was statistically significant at \( p < 0.05 \) for days after cerebral ische-

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**Fig. 4.** Effect of cerebral ischemia, induced after recovery, on reinstatement of septal syndrome (median \( \pm \) quartile deviation; \( n = 11 \)). Explanations in text. (From unpublished experiments of J. Cytawa, M. Matysek and M. Święch).

**Fig. 5.** Effect of cerebral ischemia on emotional reactivity in normal rats. Denotations as in Fig. 4. (From unpublished experiments of J. Cytawa, M. Matysek and M. Święch).
mia. In the control experiment performed on another group of rats (Fig. 5), it was found that identical cerebral ischemia did not affect emotional reactivity in normal animals.

In a similar experiment it was found that a 3-hr insulin coma produced by intraperitoneal injection of 10 units/kg of insulin also reinstated the septal syndrome in animals which had fully recovered from the effects of septal lesions (Fig. 6). These changes were statistically significant at the level of \( p < 0.01 \) or even \( p < 0.001 \). Attention should be drawn to the fact that insulin coma of the same duration produced in the same animals, but before the septal lesion, had no effect on their emotional reactivity.

![Fig. 6. Effect on insulin coma, applied after recovery, on reinstatement of septal syndrome (median ± quartile deviation; \( n = 10 \)). Explanations in text. (From unpublished experiments of J. Cytawa and J. Domalska).](image)

There is considerably experimental evidence (see 14) that the only source of energy for the brain is the oxidation of glucose because only oxygen and glucose are removed from the arterial blood of the brain and the only metabolite to enter the venous blood of the brain is carbon dioxide. Since the action of insulin is to decrease the level of blood glucose, the result is elimination of nerve cell function, especially in the cerebral cortex which has one of the highest metabolic rates (see 17). Thus, temporary decortication induced by three different methods, i.e., cortical spreading depression, cerebral ischemia and insulin
coma, all resulted in the same effect, reinstatement of the symptoms of septal lesions in recovered septal animals.

However, the marked negative effect of insulin coma on recovery of function puzzled us because insulin treatment is widely used in psychiatric therapeutics to treat various disorders. Therefore, in the next experiment the influence of insulin coma was examined, not after recovery from septal syndrome, but in the first days following production of the lesions. Insulin coma induced on the 4th and 7th postoperative day had a reverse effect, causing an immediate decrease in emotional reactivity to the normal preoperative level (Fig. 7).

The results of this experiment are presented again in Fig. 8, in which the recovery from the septal syndrome in the group treated with insulin is compared with that of the untreated septal control group. In this Figure the day in which emotional reactivity of each rat returned to a normal level for the first time and the day in which emotional reactivity remained within a normal level permanently, i.e., for at least 4 successive days, were taken as a criterion of recovery. The effect of insulin treatment was great and both groups significantly differed at the level of $p < 0.005$. 

![Graph](image-url)
Thus, an identical insulin coma produced two diametrically opposed effects depending on whether it was applied after recovery from the septal syndrome or during the acute phase of this syndrome. In the first case it reinstated the symptoms of the septal lesions; whereas in the second it facilitated the recovery of normal emotional behavior after the septal lesions. Undoubtedly these puzzling and seemingly contradictory effects do not result only from temporary abolition of the function of the cerebral cortex, but they should be rather attributed to the disorganizing action of functional decortication, which causes disruption of old and freshly formed neural connections. This would explain why the observed effects outlast the period of induced functional decortication and why they differ depending on the time elapsed after septal damage. In the early phase, just after the septal lesion, the animal suffers due to selective damage of the septal area, which is a nervous structure exerting a strong inhibitory influence (9, 13) on various components of behavior, including emotional behavior. In this period the behavior of the animal is governed by functional dominance of systems antagonistic to that of the septum, mainly of the amygdaloid nuclear complex. Functional antagonism between the septal region and amygdala was shown by Brady et al. (5), King (10) and King and Meyer (11), who found that damage of the amygdala abolishes septal hyperemotionality. Thus, in the early stage of the septal syndrome, disruption of the existing neural connections responsible for functional predominance of the antagonistic neural structures can only facilitate the recovery of normal emotional behavior. The animal relieved of the ballast of superfluous number of these connections can easier and quicker reorganize them so that they become more adequate to reinstate the emotional balance lost by experimental damage to the septal forebrain region.

When, however, the emotional balance is already reinstated due to the reorganization of neural connections, including those involving the cerebral cortex, functional decortication together with simultaneous disruption of freshly formed connections abolishes the recovery of function; and, therefore, symptoms of the brain lesion recur. This effect was invariably observed with different methods of functional decortication, i.e., cerebral ischemia, insulin coma or cortical spreading depression. This hypothesis can be supported by the observation of Trachtenberg, Hull and Buchwald (18), who found on the basis of their electrophysiological studies that the effect of spreading depression is not temporary elimination of the depressed structures but, rather, disorganization of their function, which can explain the long-lasting behavioral and physiological effects of spreading depression.

Of course, this hypothesis, which assumes that effects of insulin coma
depend on the phase of recovery of function, should be checked with other methods of functional decortication and with various brain lesions. If it is proved to be a general phenomenon, then it would be of great practical significance, particularly for psychiatric therapeutics. For example, this hypothesis would suggest the usefulness of shock treatment in acute cases, during the climax of psychotic changes, to facilitate the reorganization of new neural connections. At the same time such therapy in chronic cases and in those involving long-standing cerebral damage would be contraindicated because of its harmful potential to abolish any spontaneous recovery of function and to reinstate the original syndrome.

REFERENCES


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