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RETENTION OF THE ESCAPE REFLEX AFTER PREFRONTAL LOBECTOMY IN CATS

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From a short review of respective data (Zieliński 1966) it follows that after frontal lesions defensive classical conditioned reflexes were either enhanced or not changed, whereas instrumental avoidance reflexes were as a rule deteriorated. It is difficult to accept the explanation of the deterioration of the avoidance reflex as a consequence of the "loss of drive inhibition" (Konorski 1961) or "drive disinhibition" (Brutkowski and Wojtczak-Jaroszowa 1963, Brutkowski 1965). According to these hypotheses the same factor — increase of drive — is responsible for changes of both classical and instrumental defensive reflexes. In the case of avoidance reflex it was assumed that the overexcitement of frontal animals and their hyperreactivity to conditioned stimuli bring into action more primitive forms of defensive reactions interfering with performance of skilled instrumental response.

Recently, a new hypothesis was presented, which assumes that the different effect of frontal lesions on classical and instrumental defensive reflexes may be related to dissociation between drive and consummatory reflexes (Sołtysik and Jaworska 1967). Previous experiments on the classical defensive reflexes in frontal animals were restricted, as a rule, to the consummatory activities, whereas instrumental avoidance reflex is by definition (cf. Konorski 1967) a drive reflex. Some data suggest that neither in normal (Jaworska et al. 1962) nor in frontal animals (Sołtysik and Jaworska 1967) need there be a parallelism in drive and consummatory reflexes. In the last paper the authors have presented results of experiment on dogs with preoperatively acquired classical defensive conditioned reflexes in which after prefrontal lobectomy lower-

ing of heart rate to conditioned and unconditioned stimuli (what was considered as a decrease of the drive reflex) together with shortening of the latency of conditioned leg flexion response (increase of the consummatory reflex) were observed (Sołtysik and Jaworska 1967).

According to this hypothesis it may be expected that the instrumental escape reflex, which is also, according to above mentioned classification, a drive reflex, will be deteriorated after frontal lesions similarly as the avoidance reflex. However, it was found that frontal lesions have no effect on escape behavior (Brady et al. 1954, Thompson 1963, 1964). Moreover, it was shown that prefrontal lobectomy in cats results in the lengthening of the median latency of the avoidance responses, but in the shortening of the median latency of the escape responses to shock (Zieliński 1966).

Data concerning effects of frontal lesions on escape responses are not numerous. All of them based only on these trials in which subject failed to avoid shock and had to terminate it performing an escape response. The aim of the present study is to investigate the effects of the prefrontal lobectomy on escape responses to shock not signalled by any change in the experimental situation.

EXPERIMENTAL PROCEDURE

Sixteen adult male cats, divided before experiments into two groups, eight subjects each, were used. Experiments were carried out in a cage, 65×55×40 cm, with a grid floor to apply shock to the paws of the animal. The cage was placed in a sound-proof CR-chamber. In the middle of an oblong wall of the cage, 10 cm above the floor, a bar, 10×2 cm, was located. Similarly as in previous experiments (Zieliński and Sołtysik 1964) a series of platforms of decreasing size was used for shaping of the bar-pressing escape response. Each training session consisted of 10 trials, the intertrial intervals were of 40, 60 and 80 sec duration, randomly distributed. A trial started with activation of the grid floor and was terminated by the animal's bar-pressing escape response. If at the moment of the shock onset the bar was depressed, the bar has to be released and then pressed again to terminate the trial.

The whole experiment consisted of 28 training sessions and 6 test sessions (the 9th, 15th, 21th, 22nd, 28nd, and 34th session), 34 experimental sessions altogether. The test sessions differed from training sessions in three aspects: (i) There were 11 trials in each test sessions; (ii) If the animal did not press the bar during 60 sec of shock application, the test trial was terminated automatically; (iii) Shocks of different intensities were used: 0.5 ma in the 1st trial, 1 ma in the 2nd trial, and then shocks of increasing intensity in 0.25 ma steps until 3.25 ma in the 11th trial.

Stock intensity used during the first 8 training sessions was adjusted to the animal's behavior and was controlled by experimenter. During the first test session the shortest latency of the bar-pressing escape responses were observed when shock intensity was 0.75—1.25 ma higher than the threshold intensity. Thus, during all next training sessions shock intensity for a given animal was constant and 1 ma higher

than the lowest intensity which elicited the escape bar-pressing response during the first test session.

Treatment of the two groups of animals was different in one aspect only: a day after the 21th session the experimental group underwent prefrontal lobectomy, whereas the control group was left intact. There was a ten day rest period between the 21th and 22nd experimental sessions for all animals. The removal of prefrontal region (proreal and orbital gyri) was done by suction under Nembutal anesthesia bilaterally in one stage in aseptic conditions. After finishing the experiments, Ss from the experimental group were killed with overdoses of Nembutal and their brains were subjected to histological analysis. Reconstruction of the lesions are presented in Fig. 1.

Latencies of the escape responses were measured to the nearest 0.2 sec. Automatic programming of experiments and recording of data was provided by relay, timer and counter systems. The grid floor was activated by 50 c/sec a-c from a circuit of the constant type (100,000 ohm resistance was connected in series with a cat), which minimized the effect of changes in the animal's resistance on current flow.

RESULTS

Latencies of the escape responses. The course of learning and the general plan of the experiment are presented in Fig. 2. Median latencies of the escape responses were calculated for each subject and training session independently and then for each group and training session medians from these individual medians were estimated. As seen, most of the learning took place during the first eight training sessions. During next training sessions, when shock intensity for each subject was stable, only small changes of the daily median latencies were observed.

There were 100 trials run under stable conditions before and 100 trials after surgery and/or rest period. Median latencies for each S and 100 trials block were estimated to evaluate effect of the prefrontal lobectomy on the escape bar-pressing response. Statistical analysis of the data presented in Table I has shown that median latencies were longer before than after treatments ($p < 0.05$), whereas group effect and interaction of the two factors did not reached significance (analysis of variance, mixed design, type I, Lindquist 1953). Thus, in the course of the experiment in both groups similar shortening of the escape response latencies was observed. Examination of the individual data confirms this conclusion. Kolmogorov-Smirnov two-sample test (two-tailed) was used to compare cumulative distributions of latencies in the two 100 trials blocks (Siegel 1956). It was found that in five subjects (cats 30 and 33 from the experimental group and cats 26, 29 and 36 from the control group) there was statistically significant (at $p < 0.05$ level or better) shortening of latencies after treatments. In other cats cumulative distributions of latencies did not differ

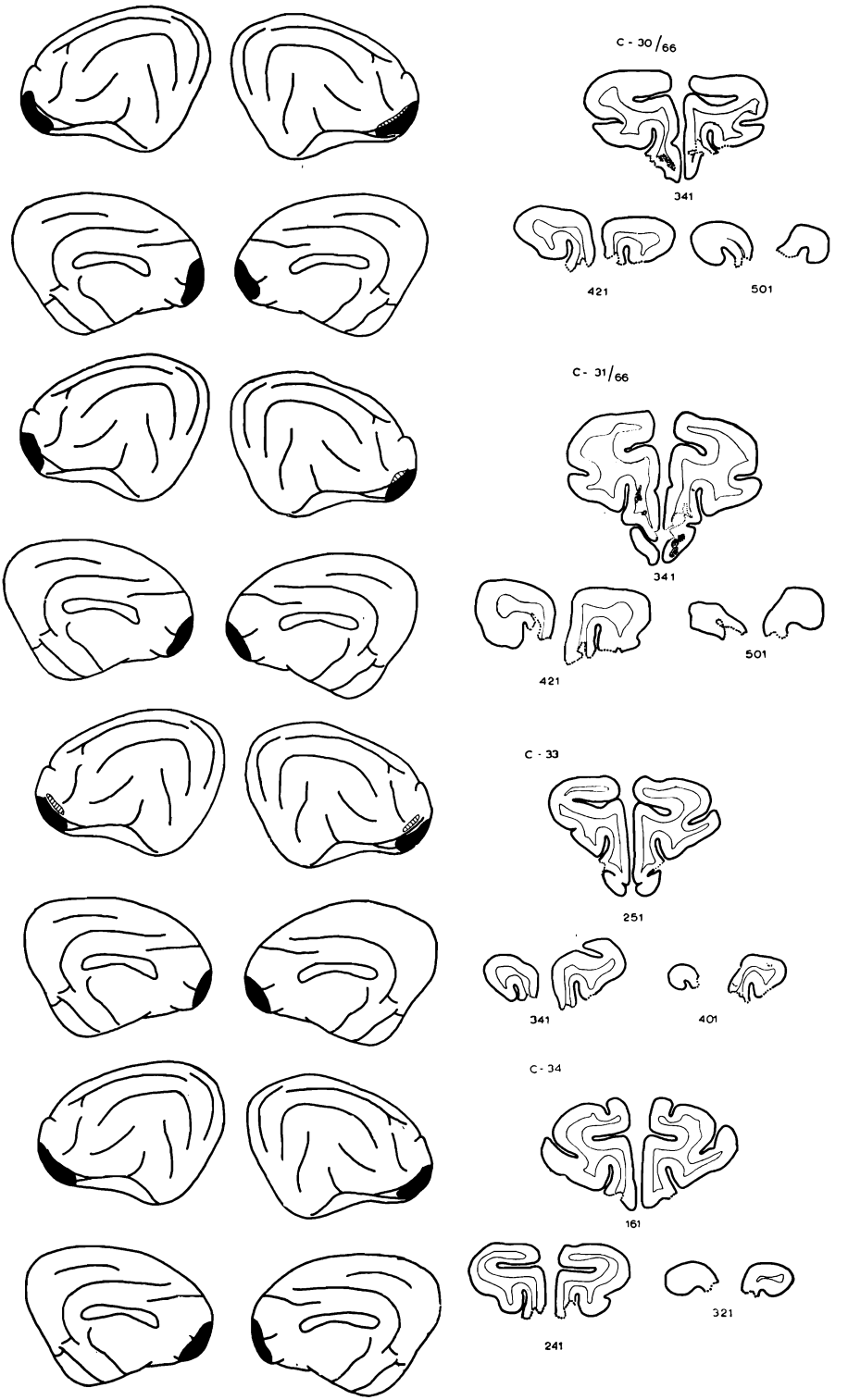
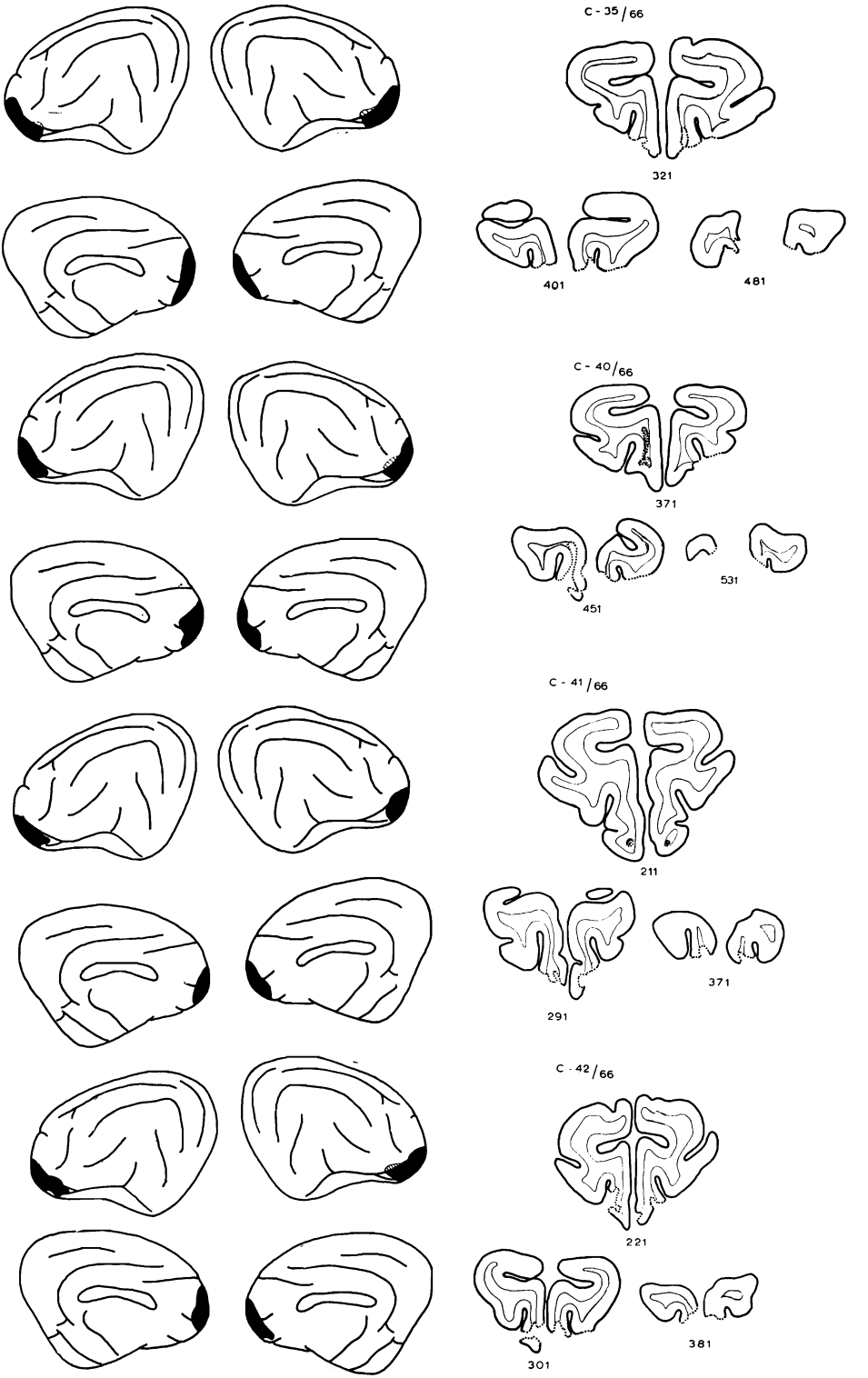


Fig. 1. Reconstruction of the lesions and the cross section



through the lesions. Blackened areas indicate extent of lesions

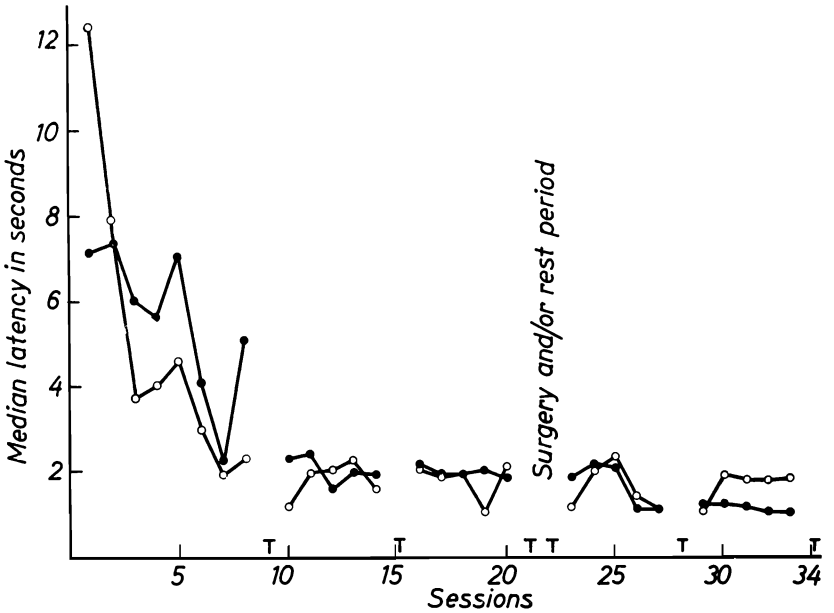


Fig. 2. Changes of the median latencies of the escape instrumental response in the course of experiment. Consecutive experimental sessions are marked on the abscissa, T, denote test sessions. Full circles, data for the control group; open circles, data for the experimental group

Table I

Median latencies (in sec) of the escape bar-pressing responses in 100 trials blocks before and after prefrontal lobectomy and/ or rest period

Experimental group			Control group		
Cat	10—20 sessions	23—33 sessions	Cat	10—20 sessions	23—33 sessions
30	2.30	1.43	25	1.10	0.96
31	2.32	2.50	26	2.45	1.21
33	1.00	0.67	27	1.12	1.09
34	1.13	1.10	29	1.56	1.07
35	0.80	0.71	32	2.07	1.98
40	2.40	2.25	36	2.50	1.55
41	1.59	1.75	38	2.40	2.10
42	2.43	2.56	39	1.50	1.59
Mean	1.75	1.62	Mean	1.88	1.44
Mdn	1.94	1.59	Mdn	1.82	1.38

statistically. It should be mentioned, however, that in cat 31 during the first three days after prefrontal lobectomy latencies of the escape response were several times longer than before surgery and then were rapidly shortened. In all other cats latencies of the escape response just before and just after treatments were of nearly the same duration.

The overall shortening of median latencies observed in both groups of cats was related to an increase in the number of escape reactions with very short latency — less than 1 sec. This information is given in Fig. 3 and 4, in which frequency histograms based on all 800 responses emitted by a given group of cats in a given block of sessions are presented. The frequency distribution of escape latencies was of reversed J-shaped form

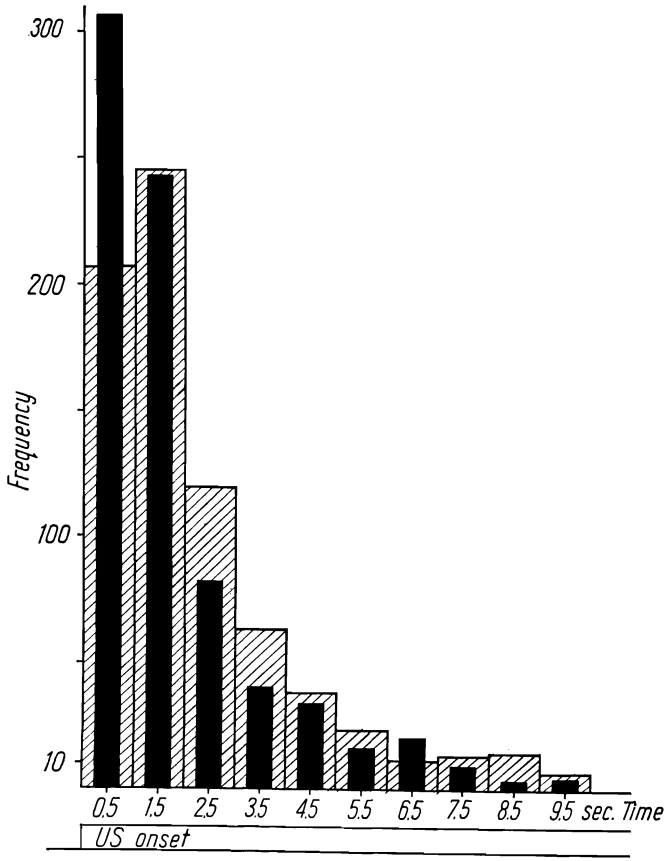


Fig. 3. Histograms showing distribution of the escape response latencies in the experimental group before (crossed area) and after (blackened area) prefrontal lobectomy. Explanation in the text

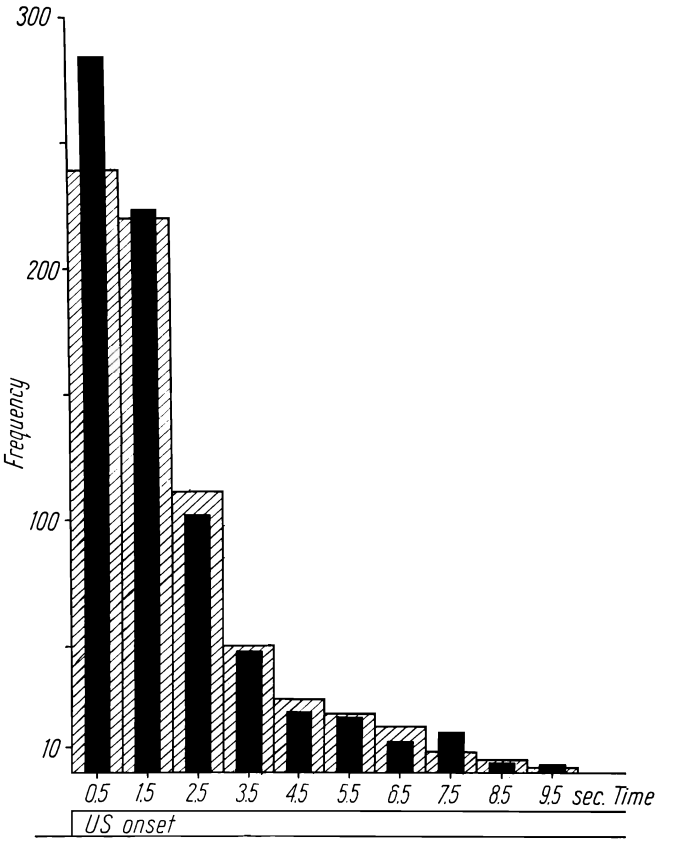


Fig. 4. Histograms showing distribution of the escape response latencies in the control group before (crossed area) and after (blackened area) rest period. Explanation in the text

and this character of distribution was not changed after operation and/or rest period but even more pronounced.

It is worth to notice that about 8% of responses had latencies longer than 10 sec with the maximum latency of 120 sec. The long-latency escape bar-pressing responses were observed when at the moment of the shock onset the animal was involved in another kind of responding: urination or defecation, attempts to go out the experimental box, or freezing. In the course of experiments a gradual decrease of this kind of responding was observed.

Performance during test sessions. Data collected during test sessions give us information about the threshold of the escape bar-pressing response and on latencies of the escape response to shock intensities higher than the threshold value. The median threshold value found

in the first test session (which, as pointed before, determined shock intensity used during following training sessions) was 1.75 ma with the range 0.50—2.50 ma and the two groups did not differ in this respect (Mann-Whitney U-test, Siegel 1956).

A general picture of changes of responding to different shock intensities in the course of experiment is shown in Fig. 5. There were three test sessions before and three after the surgery and/or rest period. Thus, each point shown in the Fig. 5 refers to 24 test trials (8 subjects and

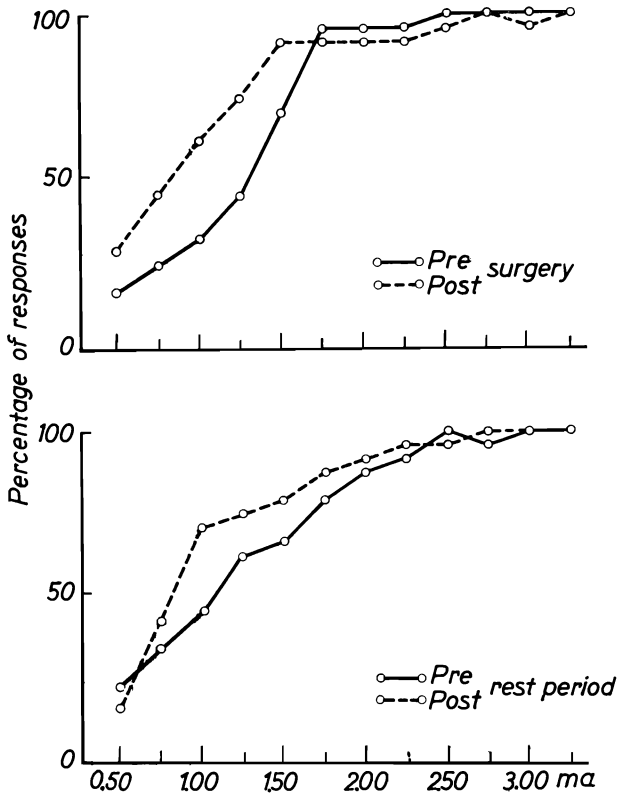


Fig. 5. Responding to different shock intensities during test sessions. Data presented on the upper part of the Figure refer to the experimental group, and data presented at the bottom — to the control group. The effects of 0.75 ma current were not measured and the appropriate points on the graph are the arithmetic means of adjacent scores

3 test trials with a given shock intensity for a given group and stage of experiment). As seen from these data, cats from both groups responded to low shock intensities more often after the surgery and/or rest period than before. Inspection of the data from consecutive test sessions had

shown that increase of the percentage of responses was gradual and there was no disturbance due to experimental procedures applied between the 3rd and the 4th test sessions. This monotonic trend was statistically significant in both groups, which did not differ in this respect (Ferguson 1965). We may infer that in the course of the experiment threshold to shock was lowered in both groups.

It it worth mentioning that cats sporadicaly did not perform the escape bar-pressing response to shock intensities higher than the threshold value within 60 sec period of their action. Such irregularities were more often after the prefrontal lobectomy than before and due to this in the experimental group level of responding to 1.75 ma and higher shock intensities was after surgery slightly lower than preoperatively. However, statistical analysis has shown that the two groups did not differ in frequency of responding to shock intensities applied in test sessions whereas there were significant differences between consecutive test sessions (analysis of variance, mixed design, type I, Lindquist 1953).

Table II

Mean and median latencies (in sec) of the escape bar-pressing responses during test sessions to shock intensities higher than those used in training sessions

Group	Index	Before treatment	After treatment
Experimental	No. of responses	62	62
	Mean	3.11	2.24
	Mdn	1.70	1.50
Control	No. of responses	69	69
	Mean	3.02	1.43
	Mdn	2.00	1.20

Inspection of the individual data indicate that in the course of experiment as a rule a shortening of latencies to all shock intensities used in test session was observed. Especially interesting are changes of latencies to intensities higher than those used in training sessions. As seen from Table II, where overall means and medians for each group and stage of experiment are presented, in both groups shortening of latencies to high shock intensities after surgery and/or rest period was observed. Statistical analysis has shown that this shortening of latencies was significant at $p < 0.005$ level, whereas group differences and interaction did not reached significance (analysis of variance, 2×2 design).

DISCUSSION

Data presented in this paper indicate that prefrontal lobectomy in cats has no effect on retention of the escape bar-pressing response from

shock. This result seems to be in disagreement with data presented in a previous paper, where after the same lesion a shortening of the median latencies of the escape bar-pressing response together with a lenghtening of the median latencies of the avoidance reflex was observed (Zieliński 1966). However, it is important to keep in mind that in the present experiment the shock, which elicited the escape response, was not signalled by any change in the experimental situation. In the previous experiment escape responses ocurred as a failure to avoid shock signalled by an acoustic stimulus and any change in performance of the avoidance reflex could have an effect on escape responses. A detailed analysis of some unpublished data from this previous experiment confirm this hypothesis. In Fig. 6 there are presented distributions of the latencies of the bar-pressing response, independently for avoidance or escape, before and after prefrontal lesion. These frequency histograms were build in the same way as those presented in Fig. 3 and 4 (i.e. each of them was based on 800 responses performed by 8 cats in a given 100 trials block of experimental sessions).

As we can see from Fig. 6 the frequency distribution of avoidance or escape bar-pressing responses was before prefrontal lobectomy of reversed J-shaped form, similarly as distributions of escape responses in the present experiment. After prefrontal lesion number of responses with very short latencies, less than 1 sec, was decreased to about 50% of the preoperative level, whereas number of responses in other time intervals was increased. In effect the form of the frequency distribution was changed from reversed J-shaped to strongly skewed to the right.

It is important to note that frequency distributions presented in Fig. 6 have regular character and introduction of shock 5 sec after the conditioned stimulus onset did not effect the shape of histograms. In other words, on the basis of the distribution of avoidance response latencies one can predict distribution of escape response latencies. The onset of shock did not increase or decrease the expected number of bar-pressing responses emitted in 5.0—6.0 sec time interval.

Now it may be concluded that shortening of the median latencies of the escape responses after prefrontal lobectomy observed in the previous experiment (Zieliński 1966) was an artefact or rather a by-product of the lenghtening of the mean and median latencies of the avoidance responses. From Fig. 6 it is seen that after the prefrontal lobectomy mode, mean, and median latencies of bar-pressing responses were shifted to the right. Due to this change of the form of frequency distribution median latencies of responses which occurred not earlier than 4 sec, or 3 sec, or even not earlier than 1 sec after the CS onset has to be shorter than before

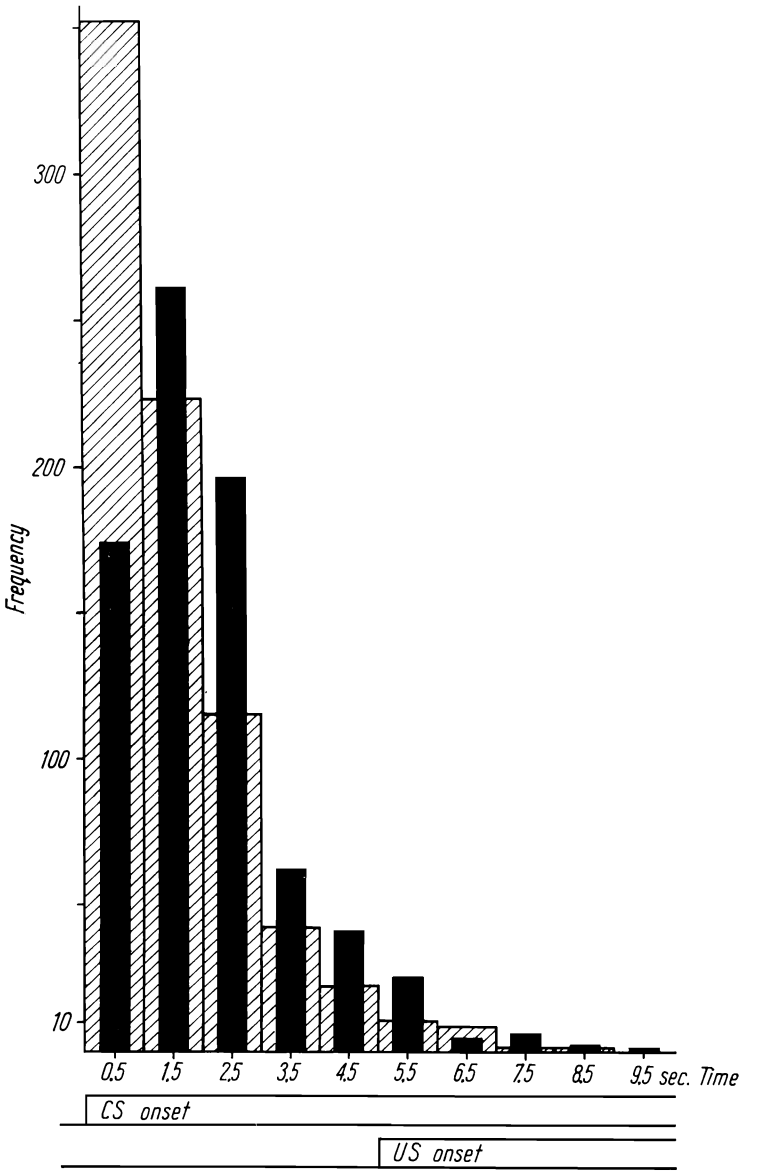


Fig. 6. Histograms showing distributions of the latencies of the bar-pressing avoidance or escape responses before (crossed area) and after (blackened area) prefrontal lobectomy. The CS—US period was of 5 sec duration, thus the five bars on the left refers to avoidance response latencies and the five bars on the right refers to escape response latencies. Additional explanation in the text

prefrontal lobectomy similarly as median latencies of the escape responses, i.e. responses which occurred not earlier that 5 sec after the

CS onset. Changes in probability of responses with latencies longer than 1.0 sec were a direct consequence of the marked decrease of the probability of short latency avoidance responses due to the prefrontal lobectomy.

Thus, the principal difference between results of the present experiment and the previous one consists in decrease of the probability of short latency avoidance responses due to the prefrontal lobectomy in cats and lack of such effect on escape responses. Initiation, not the execution of the avoidance response is deteriorated after prefrontal lobectomy.

In light of this discussion it is difficult to agree with hypotheses suggested by Sołtysik and Jaworska (1967) to explain shortening of the median latencies of the escape responses together with lengthening of the median latencies of the avoidance responses observed in the previous paper (Zieliński 1966). It has been postulated by Sołtysik and Jaworska (1967) that either pain is a separate drive and does not undergo the same reduction as fear after frontal lesion, or due to general hypermotility of prefrontal animals their "freezing" responses are diminished and consequently they are able to respond to shock faster. First of all, their own data obtained on dogs trained in defensive classical conditioned reflexes show that after medial prefrontal lesion increase of heart rate both to conditioned stimulus eliciting fear and to painful unconditioned stimulus was attenuated. Thus, as far as this index is concerned, fear and pain were showing similar postoperative changes in their study. Secondly, we did not observe in our cats trained in instrumental conditioned defensive reflexes any marked changes in general behavior, motility or "freezing" responses after prefrontal lesion. Our data give no support for neither "drive disinhibiton" nor "drive inhibition" explanation of changes of instrumental defensive reflexes after prefrontal lesions. We are in favor of hypothesis put forward by Thompson that the frontal cortex, together with the dorsomedial nucleus of the thalamus and the diffuse thalamic system, "while not critically involved in the mediation of relatively simple learned differential responses based upon escape from noxious stimulation (shock, hunger, thirst), are of special importance in situations requiring the initiation or arousal of learned anticipatory response complex" (Thompson 1964, p. 25). However, findings showing that latent periods of the classical defensive reflexes are shortened after frontal lesions (Auleytner and Brutkowski 1960, Sołtysik and Jaworska 1967) demonstrate that a deficit of the frontal animals in the initiation of learned anticipatory responses is restricted only to the avoidance reflex.

SUMMARY

Two groups of cats, 8 Ss each, were trained in bar-pressing escape response from shock not signalled by any change in the experimental situation. After acquisition of a stable escape reflex one group of cats was submitted to the prefrontal lobectomy (removal of the gyrus proreus and the gyrus orbitalis by suction), whereas the second group was left intact. It was found that prefrontal lobectomy has no effect neither on escape latency periods, nor on the threshold value of the shock eliciting the bar-pressing escape response. However, in both groups in the course of the experiment shortening of the latency periods and the lowering of the threshold value to the shock was observed.

Results obtained in the present experiment were confronted with previous data concerning effects of the prefrontal lobectomy on bar-pressing avoidance responses in cat. A comparison of the latency periods distributions has shown that prefrontal lobectomy in cats decrease the probability of the short-latency avoidance responses and has no such effect on escape responses.

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