ACTA NEUROBOL. EXP. 1972, 32: 345-359

Lecture delivered at Symposium "The frontal granular cortex and behavior"
held in Jabłonna near Warszawa
August 1971

ON THE MECHANISM OF GO-NO GO SYMMETRICALLY REINFORCED TASK IN DOGS

Jadwiga DĄBROWSKA

Department of Neurophysiology, Nencki Institute of Experimental Biology, Warszawa, Poland

Abstract. The mechanism of differentiation with asymmetrical and symmetrical reinforcement was analysed on the basis of different impairments after medial and lateral prefrontal lesions. The medial prefrontal lesions impaired the retention of asymmetrical differentiation whereas the symmetrical differentiation was slightly or not impaired at all. The lateral prefrontal lesions impaired moderately the asymmetrical differentiation only with short intertrial intervals. The disturbances of symmetrical differentiation depended on the quality of the stimuli, the separation of their sources and the quality of instrumental responses. The results support the hypothesis that the medial prefrontal cortex is involved in inhibitory control of alimentary drive functions. It is concluded that the lateral prefrontal cortex takes part in the elaboration of direct connections between conditioned stimuli and instrumental responses.

The effects of cortical lesions in dogs have shown that it is possible to distinguish at least four syndromes characteristic for various areas of the prefrontal region. Ławicka, Mishkin, Kreiner and Brutkowski (1966) and Ławicka (1969) have shown that the delayed responses are impaired specifically by the lesion of the dorsolateral part of the prefrontal cortex (proreal gyrus). Stępień and Stępień (1965), and Stępień, Stępień and Sychowa (1966) obtained characteristic disorders consisting in the so-called magneto-reaction after damage of medial aspect of the frontal lobe (Kreiner's XM area, Kreiner 1966). Szwejkowska, Kreiner and Sychowa (1963) and Brutkowski and Dąbrowska (1963) have found that disinhibition of instrumental alimentary reflexes is due to the removal of the medial prefrontal areas (*see* Brutkowski 1964). Finally, Brutkowski and Dąbrowska (1963, 1966) have shown that when the intertrial intervals are short, the removal of dorsolateral prefrontal areas produces a similar syndrome.

Brutkowski and Dąbrowska (1966) using differentiation procedure found that disinhibition of instrumental responses after cortical lesions of the medial aspect of the prefrontal regions was different from disinhibition of the same reflexes after lateral prefrontal damage. They put forward the hypothesis that the impairment of reflexes elicited after removal of the medial prefrontal cortex reflects the release of drive functions from cortical inhibitory control and the deficit in inhibition which follows lesions of the dorsolateral prefrontal cortex is due to excessive somato-perseverative tendencies. Since this hypothesis was based only on the general observation of the animal's behavior in an experimental situation, it seemed reasonable to support it by more objective evidence.

It should be recalled that in earlier experiments concerning the investigation of instrumental reflexes (Brutkowski and Dąbrowska 1966) the following procedure was used. An instrumental response (R) (placing the right foreleg on the feeder) to the positive CS was elaborated by food reinforcement. During 5 sec operation of the inhibitory CS food was never presented irrespectively whether the dog did or did not perform the trained movement. This procedure will be called "asymmetrical differentiation" to distinguish it from the method used in the present experiments which is called "symmetrical differentiation".

Differentiation procedure with symmetrical reinforcement used in the present experiments was following. Tone 1000 cycle/sec (CS_1) was excitatory for the instrumental response and tone 700 cycle/sec (CS_2) was inhibitory for the same instrumental response. If the animal performed the movement (placing the right foreleg on the feeder) during presentation of CS_1, the reward was delivered and the sound was interrupted. The CS_2 lasted always 5 sec and the animal had to withhold the movement during this time. If he did it, after a 5 sec period food was delivered and the sound was discontinued. If the animal did not perform the conditioned movement during 5 sec presentation of CS_1 or the animal performed the conditioned movement to the CS_2, food was not delivered.

Intertrial intervals of 15 and 60 sec were used for different groups of animals. Twenty trials daily 10 with CS_1 and 10 with CS_2 were given in balanced order. Ninety five per cent correct responses in 100 consecutive trials was the criterion of learning. After the animals reached criterion the experiments were discontinued for 7 days and then training started again. During five consecutive days (100 trials) verification was made. If the dog performed more than five errors, the training was prolonged to reach criterion again. If the dogs made not more than five errors only during these 100 trials, they were subjected to surgery. In four dogs with 15 sec intertrial intervals the medial prefrontal cortex was ablated. It was intended to remove the area pregenualis I, II and III (PG I, PG II, PG III) up to the anterior cingulate gyrus and medial portion of the proreal gyrus (PR). In the other 8 dogs (4 with 15 sec and 4 with 60 sec intertrial intervals) the lateral prefrontal cortex was removed. This lesion should include the dorsolateral part of proreal gyrus (PR) and orbital gyrus I and II (ORB I', ORB I'', ORB II) up to the presylvian fissure. Figure 1 shows the schemes of lateral and medial aspects of the

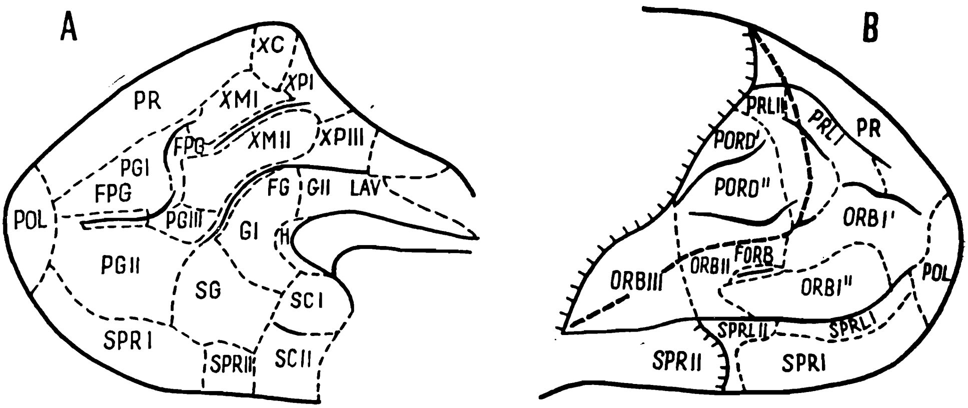

Fig. 1. Medial (*A*) and lateral (*B*) aspects of the prefrontal cortical areas. Heavy interrupted line in *B* shows the areas lying inside of the presylvian fissure.

prefrontal cortical areas in dog (Kreiner 1966). Figure 2 shows examples of the smallest and largest lesions performed in these dogs.

On the eighth day after operation the retention of previously elaborated reflexes was verified. Table I shows the number of trials and errors made by dogs in asymmetrical differentiation pre-operatively and post-operatively according to the data obtained by Brutkowski and Dąbrowska (1966). Table II represents similar data obtained in dogs trained in symmetrical differentiation (Dąbrowska 1971). Criterial trials and errors are included in the results. As seen in Table I, in asymmetrical differentiation both groups of animals trained with 15 and 60 sec intertrial intervals were moderately impaired after medial cortical prefrontal lesions, whereas the animals subjected to the lateral prefrontal lesions were moderately impaired only when the intertrial intervals were short (15 sec). The animals trained with long intertrial intervals (60 sec) were not impaired at all after lateral prefrontal lesions.

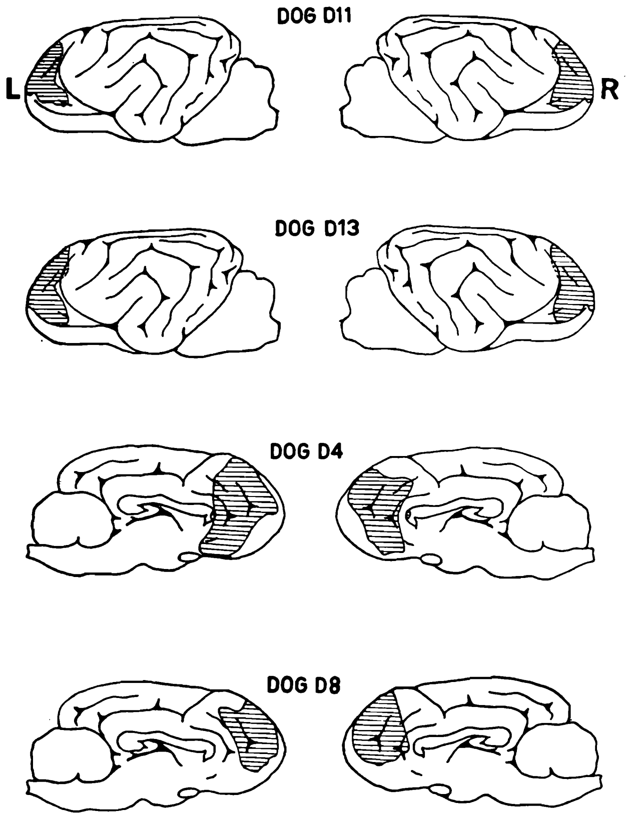

Fig. 2. Lateral and medial prefrontal lesions in representative dogs. Hatched areas represent extent of cortical damage. (From Dąbrowska 1971.)

On the contrary, among 8 animals trained in symmetrical differentiation (Table II) and in which the medial prefrontal cortex was ablated, 4 dogs were not impaired at all and 4 dogs were slightly impaired, one of them made 14 errors, and the others about 29 errors.

Histological verification of lesions showed that the extent of medial lesions varied in particular dogs, and it was difficult to say which part of this area was responsible for the slight impairment in the symmetrical differentiation performance, and whether it is an XM area or subcortical tissue. This problem will be discussed in another paper.

On the other hand, all dogs trained in symmetrical differentiation, in which the lateral prefrontal cortex was removed, were very strongly impaired. This impairment did not depend on the duration of intertrial intervals. Among 8 dogs, only one reached criterion after operation, but training after operation was longer than before. Dogs 10 and 11 trained as long as one year after operation could not reach criterion during this

TABLE I

Pre-operative and post-operative trial and error scores in asymmetrical differentiation for individual subjects. Conditioned stimuli 1000 and 700 cycle/sec tones. One loudspeaker

Lesion	Interval (in sec)	Dog	Pre-operative Trials	Pre-operative Omission errors	Pre-operative Commission errors	Post-operative Trials	Post-operative Omission errors	Post-operative Commission errors
Medial	15	34	1040	13	263	250	0	60
		35	720	3	172	230	0	32
		36	1210	0	451	430	2	94
		37	560	7	143	490	2	85
	60	41	200	2	48	210	0	36
		42	340	0	63	380	66	65
		43	440	0	76	190	1	35
		58	260	0	51	210	0	43
Lateral	15	30	720	1	195	540	1	92
		31	1040	1	346	540	0	64
		32	1660	6	395	280	3	22
		33	400	0	120	310	0	41
	60	38	610	3	163	100	0	3
		39	270	0	75	120	0	8
		40	300	0	81	100	0	5
		52	360	2	74	100	0	4

TABLE II

Pre-operative and post-operative trial and error scores in symmetrical differentiation in individua subjects. Conditioned stimuli 1000 and 700 cycle/sec tones. One loudspeaker

Lesion	Interval (in sec)	Dog	Pre-operative Trials	Pre-operative Omission errors	Pre-operative Commission errors	Post-operative Trials	Post-operative Omission errors	Post-operative Commission errors
Medial	15	1	1300	0	404	100	0	3
		2	640	0	199	120	0	9
		3	520	1	149	220	1	28
		4	740	1	204	280	3	26
	60	5	540	0	161	120	0	9
		6	580	0	236	220	2	26
		7	600	0	121	160	0	14
		8	1320	54	225	120	0	7
Lateral	15	9	820	0	210	800	66	253
		10	720	0	202	1460	7	316
		11	680	0	217	1980	156	587
		12	500	1	151	1180	101	182
	60	13	560	0	156	660	84	74
		14	300	0	72	1100	98	285
		15	440	0	127	800	64	212
		16	360	0	89	800	105	123

time. The training of other dogs after lateral prefrontal lesions was discontinued after 800 trials.

The impairment of the performance in symmetrical differentiation task after lateral prefrontal lesions was characterized by the large number of errors made to both stimuli CS_1 and CS_2. On the contrary the errors in asymmetrical differentiation after lateral (15 sec intertrial intervals) and medial lesions were made almost exclusively to CS_2 [1]. Another important difference between these two tests after lateral lesions was that the animals trained in symmetrical differentiation changed their behavior during the course of experiments either performing the instrumental response to both stimuli or, on the contrary, failed to respond to either stimulus. These two phases were divided by chaotic performance (Fig. 3).

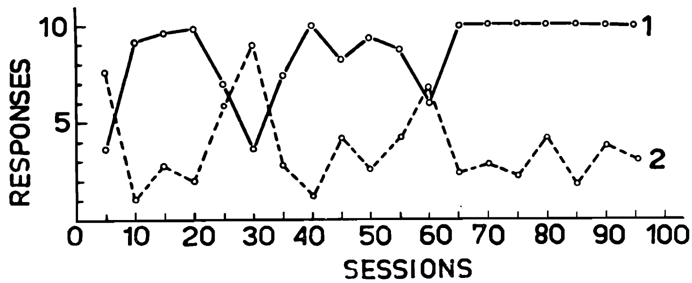

Fig. 3. Correct responses to the CS_1 (continued line) and CS_2 (interrupted line) in dog 11. Each point represent the mean number of correct responses from consecutive sessions.

On the basis of these results the following hypothesis might be proposed. In the asymmetrical differentiation the cortical center of CS_1 is connected with the alimentary drive center and through it with the center of instrumental response. There is also direct connection between the cortical center of CS_1 and cortical center of that response (R) (Wyrwicka 1960). Inhibition of instrumental response produced by CS_2 may be accomplished through the inhibitory connection between the cortical center of CS_2 and unconditioned alimentary drive center. The correct performance to the CS_2 depends on the excitatory level of the drive center (D). Ablation of the medial prefrontal cortex which is suggested as the cortical inhibitory area (CIA) for unconditioned alimentary drive center released this center from cortical inhibitory control. In such

[1] Only one animal, dog 42 (Table I) trained in asymmetrical differentiation made many omission errors after medial prefrontal lesions. This result is unusual in comparison with post-operative performance of other dogs trained in this test. Up to now, this result is very difficult to explain.

a case where only one movement may be reinforced by food, this movement will be performed up to the moment when the inhibitory connection between CS_2 and D gets stronger.

Let us suppose that in symmetrical differentiation there is probably not single instrumental response, which is elicited by CS_1 and inhibited by CS_2, but there are two responses: flexor response produced by CS_1 and extensor response produced by CS_2. The alimentary drive center is activated by both conditioned stimuli CS_1 and CS_2 and direct connections only between cortical centers of the stimuli and cortical centers of instrumental responses, reciprocally, define which movement should be performed to which stimulus. Such a mechanism was proposed by Wyrwicka (1966) for two different instrumental responses to two conditioned stimuli. If this mechanism is applied to symmetrical go–no go differentiation, the ablation of the medial prefrontal cortex will not result in the impairment of this test because the conditioned direct connections between CS_1 and flexor response (R_f) and CS_2 and extensor response (R_e) remain intact. These very connections determine which response should be performed to which stimulus, and stronger excitation of the alimentary drive center can be manifested in better performance. Results of these experiments supported the hypothesis presented by Brutkowski and Dąbrowska (1966) that the medial prefrontal cortex is really the inhibitory area for alimentary drive functions.

Let us assume that the lateral prefrontal cortex in dogs is involved in elaboration of conditioned connections between cortical centers of the conditioned stimuli and responses. If this area is damaged, the alimentary drive center being connected with two responses cannot determine which movement should be performed to which stimulus, because the connections between conditioned cortical centers of stimuli and responses are interrupted. In such a case both responses may be performed to both stimuli. Such type of behavior was manifested by dogs after lateral prefrontal lesions in symmetrical differentiation experiments.

In the case of asymmetrical differentiation in which there is only one trained movement, it can be defined by the drive center and therefore the performance of this task shouldn't be impaired after lateral prefrontal damage. However, this was true only in dogs trained with long (60 sec) intertrial intervals. The dogs trained with short (15 sec) intertrial intervals were moderately impaired after dorsolateral prefrontal lesions. To answer the question why it is so, let us analyse the differences in behavior of normal animals trained with short and long intertrial intervals in symmetrical and asymmetrical differentiation tests.

Table III shows the number of trials and intertrial responses made by dogs trained in asymmetrical and symmetrical differentiation. (The

TABLE III

Number of trials and intertrial responses in asymmetrical and symmetrical differentiation during training with 15 sec and 60 sec intertrial intervals

Differentiation	15 sec interval			60 sec interval		
	Dog	Trials	Intertrial responses	Dog	Trials	Intertrial responses
Asymmetrical	Kondor	270	12	Fucek	135	18
	Mały	345	136	Rudy	150	10
	Bąk	420	325	Czarek	165	0
	Kaprys	435	114	Diablik	180	14
	Poker	525	319	Reks	180	72
	Druh	555	52	Filutek	180	17
	Beza	555	670	Mops	195	22
	Kibic	675	105	Kudłacz	270	40
Σ		3783	1733		1455	193
Symmetrical	1	620	39	5	270	4
	2	320	71	6	290	41
	3	260	132	7	300	1
	4	370	53	8	250	1
	9	410	27	13	280	52
	10	360	53	14	150	9
	11	340	329	15	220	57
	12	660	242	16	180	0
Σ		3340	946		1940	165

data in this Table concerning the results of asymmetrical differentiation were taken from the paper of Brutkowski and Dąbrowska 1965). It may be seen that the dogs trained with 15 sec intertrial intervals needed many more trials to reach criterion in both tests (asymmetrical and symmetrical) than the dogs trained with 60 sec intertrial intervals. Moreover, the dogs trained with short intervals made many more intertrial responses than the long interval dogs. It is interesting to note that the dogs which have about 8–10 sec real interval to react (because the rest of the 15 sec interval was spent on the conditioned and unconditioned responses) made many more intertrial movements than the dogs which had not less than a 50 sec interval to react. This phenomenon could be interpreted in various ways. Brutkowski and Dąbrowska (1965) gave the following two possible interpretations.

According to the first one. "... the development of differentiation defined in terms of suppression rate of the CR on inhibitory trials and during intertrial intervals, is more rapid under circumstances of CS_1 presented at long intervals. This can be explained by an increased inhibition with long intervals. After a long interval the inhibitory trial is associated with a phase of reduced facilitatory effect following the preceding positive trials — a condition which is beneficial for inhibition.

A slow development of differentiation trained at short intertrial intervals, which is reflected by a low suppression rate of the CR on inhibitory trials and excess of response during intervals, may be attributed to the fact that after a short interval the inhibitory trial is associated with a high level of facilitatory effect resulting from the preceding positive trial — a factor which clearly interferes with inhibition".

Another possible explanation of this fact is: "... with short intervals, the chance of presenting the food reinforcement is greater. Hence, there is the possibility that a high rate of responding during intertrial intervals in the short interval situation is due to this adventitious secondary reinforcement".

Turning the effects of ablations of the lateral prefrontal cortex we have to take under consideration the following factors making the inhibitory connections very weak:

1. Food reinforcement was related to the trained movement which was facilitated also by the alimentary background of experimental conditions.

2. Inhibitory stimulus had a small excitatory effect by generalization with CS_1, which can be manifested in small acceleration of the heart rate (Gantt and Hoffmann 1940). This stimulus was primarily an excitatory one and Szwejkowska (1959) discovered that such an inhibitory reflex can be transformed to an excitatory one very easily.

3. Food reinforcement was very small in these experiments (one small piece of bread) and inhibition of the drive center was very weak after positive trial. If the aftereffect of the drive center excitation observed in defensive reflexes after presentation of unconditioned stimulus (US) lasting even 8–10 sec (Sołtysik 1960, Jaworska and Sołtysik 1962) may be applied to alimentary reflexes, the CS_2 applied on the higher excitatory background of the drive center could induce instrumental response.

It can also be added, that the asymmetrical differentiation test with 15 sec intertrial intervals was impaired after proreal lesions while the same test with 60 sec intertrial intervals was not impaired (Brutkowski and Dąbrowska 1966). Small hippocampal lesions also disinhibited this test (J. Dąbrowska, unpublished data).

It can be concluded on the basis of these considerations that impairment in go–no go asymmetrical differentiation with 15 sec intertrial intervals cannot be explained unequivocally. Many factors affect it and these disorders after lateral prefrontal lesions may be unspecific.

If the hypothesis proposing two different mechanisms of elaboration of asymmetrical and symmetrical differentiation tests is correct, the symmetrical differentiation of two instrumental responses (right leg–left leg) to two conditioned stimuli should be impaired after lateral prefrontal lesions. Two dogs were subjected to the experiments in which tone 1000 cycle/sec (CS_1) was excitatory for the placing of the right foreleg on the feeder and tone 700 cycle/sec (CS_2) excitatory for the placing of the left foreleg on the feeder, each response evoked by the proper stimulus was reinforced by food. Although, the difficulty of elaboration of such differentiation was strong (even the criterion of learning was diminished to 90% of correct responses), the dogs after removal of the lateral prefrontal cortex were not impaired. The same type of experiments was made by J. Stępień and L. Stępień (unpublished data) and similar results were obtained.

The problem arose as to why after lateral cortical prefrontal lesions the symmetrical differentiation elaborated by go–no go procedure is severely impaired while the symmetrical differentiation elaborated by go left–go right procedure, using the same stimuli is not. To answer this question, in further experiments we changed the character of the stimuli in various ways, using only go–no go both reinforced procedure.

In the next series of experiments 6 dogs were trained to place the right foreleg on the feeder in response to the tone 1000 cycle/sec (CS_1) and refrain from this movement in response to the (CS_2) buzzer. After the dogs reached criterion, in 3 of them the lateral prefrontal cortex and in the other 3 dogs the medial prefrontal cortex was removed. Retention of the test in all dogs after operation was almost perfect (Table IV). This data shows that the animals were able to solve the go–no go sym-

TABLE IV

Pre-operative and post-operative trial and error scores in symmetrical differentiation in individual subjects. Conditioned stimuli 1000 cycle/sec tone and buzzer. Two loudspeakers separated 10 cm from each other

			Pre-operative			Post-operative		
Lesion	Interval (in sec)	Dog	Trials	Omission errors	Commission errors	Trials	Omission errors	Commission errors
Lateral	15	28	140	0	12	140	0	10
	60	29	140	0	11	140	0	9
	60	30	240	0	21	140	1	3
Medial	60	31	200	3	18	100	1	1
	60	32	300	0	41	100	0	5
	15	33	400	0	54	100	0	3

metrically reinforced task after lateral prefrontal ablation, if the difference between the quality of the stimuli was large.

Analysing the two differentiation tasks to two tones and to tone vs. buzzer — we can find the following differences between them: first, tones 1000 cycle/sec are qualitatively very similar and generalization of these stimuli was very strong as judged by the number of errors to the no go stimulus (72–409). On the contrary tone 1000 cycle/sec and buzzer are qualitatively dissimilar and generalization of the stimuli was small. The animals made only few errors (11–54) to the no go stimulus.

The second difference between the two pairs of stimuli was due to the one or two sources of sounds. A single loudspeaker situated in front of the dog was used in differentiation of two tones, while the two loudspeakers situated in front of the dog separated by 10 cm were used for buzzer vs. tone experiments.

Thus, two factors could play a role in the difference of our results: generalization of the stimuli and the orienting response to the source of each sound.

In order to answer this question 4 dogs were trained in go–no go both reinforced procedure using tone 1000 cycle/sec (CS_1) and buzzer (CS_2), both stimuli operating from the same place, situated in front of the animals. Another group of 4 animals was trained by the same method, but the conditioned stimuli, which were 1000 cycle/sec (CS_1) and 700 cycle/sec (CS_2) tones, were emitted from two loudspeakers situated in front of the animals and separated by 10 cm. The last group including also 4 dogs was trained with two tones, 1000 cycle/sec (CS_1) and 300 cycle/sec (CS_2), operating from the single loudspeaker situated in front of the animals. After the dogs reached criterion the lateral prefrontal cortex (gyrus orbitalis) was ablated.

Table V shows that two groups of animals, those trained to tone 1000 cycle/sec vs. buzzer, and to tone 1000 cycle/sec vs. tone 300 cycle/sec were unimpaired. On the other hand, the group trained with two tones, 1000 cycle/sec and 700 cycle/sec separated by 10 cm was impaired, but all the dogs reached criterion. The results obtained in the last group of animals showed that the separation of the sound sources might be important because these animals reached criterion, after operation.

To investigate the significance of orienting response in post-operative performance of this test, the following final procedure was introduced.

Three dogs were trained in go–no go both reinforced procedure to one conditioned stimulus which was tone 1000 cycle/sec. This stimulus was excitatory for the movement if it was emitted from the loudspeaker situated on the right side of the dog. The same tone emitted by the

TABLE V

Pre-operative and post-operative trial and error scores in symmetrical differentiation after lateral prefrontal lesions in individual subjects

Conditioned stimuli	Interval (in sec)	Dog	Pre-operative			Post-operative		
			Trials	Omission erorrs	Commission errors	Trials	Omission errors	Commission errors
CS_1—Tone 1000 cycle/sec	60	36	120	0	8	100	0	1
CS_2—Buzzer	15	37	180	0	28	100	0	3
One loudspeaker	60	38	180	1	9	160	0	11
	15	39	680	1	159	100	2	3
CS_1—Tone 1000 cycle/sec	60	40	480	3	56	100	3	2
CS_2—Tone 300 cycle/sec	15	41	760	3	140	220	0	16
One loudspeaker	60	42	460	20	25	140	1	6
	15	43	400	0	54	120	0	7
CS_1—Tone 1000 cycle/sec	60	44	680	0	138	740	35	84
CS_2—Tone 700 cycle/sec	15	45	720	0	178	840	25	88
Two loudspeakers	15	46	840	1	178	640	18	100
	60	47	720	0	193	480	3	78

loudspeaker situated on the left side of the dog was inhibitory for the same movement. After the dogs reached criterion bilateral removal of the prefrontal cortex (orbital gyrus) was made and post-operative retention was verified. Table VI shows that in spite of difficulties in elabo-

TABLE VI

Pre-operative and post-operative trial and error scores in symmetrical differentiation after lateral prefrontal lesions in individual subjects. Conditioned stimuli: CS_1, tone 1000 cycle/sec on the right side of the dog; CS_2, tone 1000 cycle/sec on the left side

Dog	Interval (in sec)	Pre-operative			Post-operative		
		Trials	Omission errors	Commission errors	Trials	Omission errors	Commission errors
49	15	1000	32	183	120	0	8
50	60	560	53	33	120	5	1
51	60	1160	49	200	100	0	5

ration of differentiation during pre-operative training, the dogs after operation were not impaired.

Summarizing the above results the following conclusions can be drawn:

1. The go–no go symmetrically reinforced differentiation is severely

impaired after lateral prefrontal lesions if the two conditioned stimuli are very similar (tones 1000 and 700 cycle/sec) and there is a single source of these stimuli.

2. This test is also impaired after very similar lesions, but the animals can reach post-operative criterion, if the conditioned stimuli are similar (tones 1000 and 700 cycle/sec), but their sources are separated by 10 cm.

3. The go–no go symmetrically reinforced task is not impaired after lateral prefrontal operation if the conditioned stimuli are dissimilar (tone vs. buzzer, and tone 1000 cycle/sec vs. tone 300 cycle/sec). In this case the one or two sources of these stimuli do not affect the course of pre-operative and post-operative trainings.

4. If the two conditioned stimuli are very similar (tones 1000 and 700 cycle/sec) and there is one sound source, the left leg–right leg differentiation with symmetrical reinforcement is not impaired after lateral prefrontal lesions.

5. If the same tone (1000 cycle/sec) presented from the two places (right side and left side of the dog) is used, the go–no go symmetrically reinforced test is not impaired after lateral prefrontal lesion.

6. The go–no go asymmetrically reinforced differentiation using long (60 sec) intertrial intervals is not impaired after lateral prefrontal ablations when the very similar tones (1000 and 700 cycle/sec) as conditioned stimuli were used.

On the basis of these results it may be concluded that the lesions in the lateral prefrontal cortex produce impairment in the symmetrically reinforced differentiation only in those cases in which both stimuli are very similar to each other and the instrumental responses elicited by these stimuli are also akin. When both of the conditioned stimuli elicit the same orienting response and are similar to each other, then the test is impaired after lateral prefrontal lesions, whereas when they elicit different orienting responses, it is not impaired.

On the other hand if the stimuli are quite distinct from each other, the test is not impaired even if they operate from the same source. Conversely if instead of go–no go test the right leg–left leg test is used (that is the responses are not akin) then the lateral prefrontal lesion does not produce any impairment irrespectively of the character of the stimuli.

Let us try to analyze the location of cortical centers of conditioned stimuli and instrumental responses in our experiments. Cortical centers of two tones (1000 and 700 cycle/sec), which are very similar, have to be very close to each other and flexor and extensor responses of the same foreleg have also to be represented very closely in the cortex. Such dissimilar stimuli as tone 1000 cycle/sec and buzzer have larger separation of cortical representations than similar stimuli, and separation of cortical representations of left foreleg flexion and right foreleg flexion is also larger than flexion and extension of the same foreleg.

If it is so, the impairment after lateral prefrontal lesion in go–no go symmetrically reinforced differentiation would be limited only to those cases in which the centers of the conditioned stimuli are very close and orienting responses to these stimuli are almost the same. However, lateral prefrontal lesions fail to impair the symmetrically reinforced differentiation either when the cortical centers of the stimuli, or the centers of instrumental responses are largely separated.

This investigation was partially supported by Foreign Research Agreement No. 05-275-2 of the U. S. Department of Health, Education and Welfare under PL 480.

REFERENCES

BRUTKOWSKI, S. 1964. Prefrontal cortex and drive inhibition. *In* J. M. Warren and K. Akert (ed.), The frontal granular cortex and behavior. McGraw-Hill Book Co., New York, p. 242–270.

BRUTKOWSKI, S. and DĄBROWSKA, J. 1963. Disinhibition after prefrontal lesions as a function of duration of intertrial intervals. Science 139: 505-506.

BRUTKOWSKI, S. and DĄBROWSKA, J. 1965. Temporal factors in differentiation of instrumental conditioning variety. Acta Biol. Exp. 25: 359–362.

BRUTKOWSKI, S. and DĄBROWSKA, J. 1966. Prefrontal cortex control of differentiation behavior in dogs. Acta Biol. Exp. 26: 425–439.

DĄBROWSKA, J. 1971. Dissociation of impairment after lateral and medial prefrontal lesions in dogs. Science 171: 1037–1038.

GANTT, W. H. and HOFFMANN, W. C. 1940. Conditioned cardio-respiratory changes accompanying conditioned food reflexes. Amer. J. Physiol. 129: 360–361.

JAWORSKA, K. and SOŁTYSIK S. 1962. Studies on the aversive classical conditioning. 3. Cardiac responses to conditioned defensive (aversive) stimuli. Acta Biol. Exp. 22: 193–214.

KREINER, J. 1966. Reconstruction of neocortical lesions within the dog's brain: Instructions. Acta Biol. Exp. 26: 221–243.

ŁAWICKA, W. 1969. A proposed mechanism for delayed response impairment in prefrontal animals. Acta Biol. Exp. 29: 401–414.

ŁAWICKA, W., MISHKIN M., KREINER, J. and BRUTKOWSKI S. 1966. Delayed response deficit in dogs after selective ablation of the proreal gyrus. Acta Biol. Exp. 26: 309–322.

SOŁTYSIK, S. 1960. Studies on the avoidance conditioning. III. Alimentary conditioned reflex model of the avoidance reflex. Acta Biol. Exp. 20: 183–192.

STĘPIEŃ, I. and STĘPIEŃ L. 1965. The effects of bilateral lesions in precruciate cortex on simple locomotor conditioned response in dogs. Acta Biol. Exp. 25: 387–394.

STĘPIEŃ, I., STĘPIEŃ L. and SYCHOWA B. 1966. Disturbances of motor conditioned behavior following bilateral ablations of the precruciate area in dogs and cats. Acta Biol. Exp. 26: 323–340.

SZWEJKOWSKA, G. 1959. The transformation of differentiated inhibitory stimuli into positive conditioned stimuli. Acta Biol. Exp. 19: 151–159.

SZWEJKOWSKA, G., KREINER J. and SYCHOWA B. 1963. The effect of partial lesions of the prefrontal area on alimentary conditioned reflexes in dogs. Acta Biol. Exp. 23: 181–192.

WYRWICKA, W. 1960. An experimental approach to the problem of mechanism of alimentary conditioned reflex, type II. Acta Biol. Exp. 20: 137–146.

WYRWICKA, W. 1966. The effect of food reinforcement on the level of alimentary excitation. Acta Biol. Exp. 26: 183–191.

Received 16 October 1971

Jadwiga DĄBROWSKA, Department of Neurophysiology, Nencki Institute of Experimental Biology, Pasteura 3, Warszawa 22, Poland.