The Nencki Institute of Experimental Biology Polish Academy of Sciences

ACTA BIOLOGIAE EXPERIMENTALIS

Journal devoted to basic research in brain physiology and behavioral sciences

Vol. 28, No. 1, 1968

Polish Scientific Publishers Warsaw

50 Years of the Nencki Institute

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Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 1—10, 1968

CONDITIONED REFLEXES REINFORCED BY DIRECT AND INDIRECT FOOD PRESENTATION

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It is seldom realized that the Pavlovian classical food conditioning is much less „classical" than other conditioning procedures, such as, acid conditioning, leg flexion conditioning, or eye blink conditioning, to mention the most widely used types. The term „classical" implies that, among others, the animal's behavior does not control the occurrence and intensity of the reinforcing stimulus. Yet the normal procedure of food conditioning represents an obvious violation of this rule: it is up to the dog whether, when and how the available gustatory stimuli be applied upon the receptor surface at the mouth. In contrast to most other techniques of classical conditioning where the CS is a signal of an inevitable occurrence of the US, here the CS is a signal of a mere opportunity to approach and make a contact with the US. What is paired in this procedure is not simply the CS (or, initially, an indifferent stimulus), with the US, but there must occur in the CS-US interval an appetitive (i.e., drive) reflex of approaching and seizing the food, and only then the gustatory US impinges upon the mouth receptor eliciting eventually the unconditioned consummatory reflexes. In other words, the „classical" food CS should be considered a double CS eliciting both drive and consummatory CRs. One important prediction arises from these considerations. A poorer conditioning of a given response should be expected if the same CS elicits simultaneously an antagonistic CR. The view that the hunger drive reflexes (i.e., appetitive behavior) and the food-consummatory act are antagonistic, or mutually inhibitory activities of an organism was recently expressed by Sołtysik and Konorski (1966) and Konorski (1967). This

concept could be traced back to the ethologists' ideas concerning the neural organization of the instinctive behavior (e.g., Tinbergen 1951). One may assume, therefore, that consummatory conditioning using food as the US may be improved by elimination of the appetitive behavior that normally precedes the gustatory stimulation.

It seems conceivable that the drive CR could be effectively eliminated if the US were applied directly upon the receptive surface of the mouth. Such an application of the US should improve the process of conditioning of the consummatory responses. The present experiments were designed to test this assumption. Comparison was made between the licking responses occurring to the CS paired either with the food presented in the bowl (B-group) or with the food injected directly into the mouth through the cheek fistula (M-group). For technical reasons liquid substances were used in these experiments as the USs (instead of solid food), namely, water in the experiment I, and diluted milk in the experiment II, so that no salivary CRs were recorded. Instead, the mouthing and licking movements could be reliably observed and they have been investigated in this study.

EXPERIMENT I

Conditioned licking in water-conditioned dogs

Material and method. Eight adult mongrel male dogs were used in this study. The animals were experimentally naive. In four of them a cheek fistula was made prior to the training. This enabled us to introduce water directly into the mouth through a rubber tube connected to a container placed about 120 cm above the dog's head. The lower end of the tube was attached to a hollow plug-and-socket injection assembly which could be inserted into the fistula.

Experiments were carried out in a sound-proof CR chamber. Animals were placed in harnesses on a Pavlovian stand. A dry diet, including a salty breakfast was applied to secure a definite thirst drive in dogs.

Training began usually with a habituation to the experimental situation. Dogs were accustomed to the stand daily and at the same time measurements were made of the amount and rate of drinking water from a bowl. The average drinking rate was about 150 ml per minute, and this rate was adopted for injecting water through the fistula. After a few days, when dogs seemed adapted to the CR chamber and when presentation of water elicited reliably the drinking response, two pseudoconditioning sessions were carried out. Each of them consisted of ten presentations of a metronome (80 beats per minute, 5 sec duration) and four presentations of water (being the future US). The schedule was the following: five presentations of metronome, four presentations of water, and again five times the metronome. It was found that no licking or mouthing responses were elicited by the metronome during these two sessions. During the following sessions the metronome (called henceforth the CS) was paired with water (the US). Water was always presented in five 1 sec jets of 3 ml each, the intervals

between them being also 1 sec. Thus, the US lasted 10 sec and amounted to 15 ml of water. The CS started always before the US and terminated in the fifth second of the US. The CS-US interval (meaning the interval between the onsets of the CS and US) was 2 sec in the first two sessions and was gradually extended by 1 sec every two days till it reached 5 sec. All the consecutive sessions consisted of four trials each and the CS-US interval was 5 sec. The intertrial intervals varied from 2 to 3 min.

The conditioned licks were counted by two observers simultaneously. As the size of the CR we took the number of licks (and mouthing movements like chewing and swallowing) that occurred during the 5 sec of the CS-US interval minus half of the number of such responses during the 10 sec immediately preceding the onset of the CS. In this way the possible time-CR was subtracted and the scores obtained may be considered as the actual CR to the metronome.

After each session the dogs were allowed to drink ad libitum, and the amount of water drunk was measured to obtain some estimation of their thirst drive. No water was available in their home cages.

Following 27 days of training the animals were subjected to an acute experimental extinction of the CR by presenting the nonreinforced CS every minute till they stopped responding in the four consecutive trials or till the number of trials reached 60.

Results. Fig. 1 represents the average number of conditioned licking and mouthing responses in two groups of dogs during last 20 sessions. The group which received water directly into the mouth showed a greater number of licks than the animals drinking from a bowl. However, the results are not conclusive. The difference is statistically nonsignificant

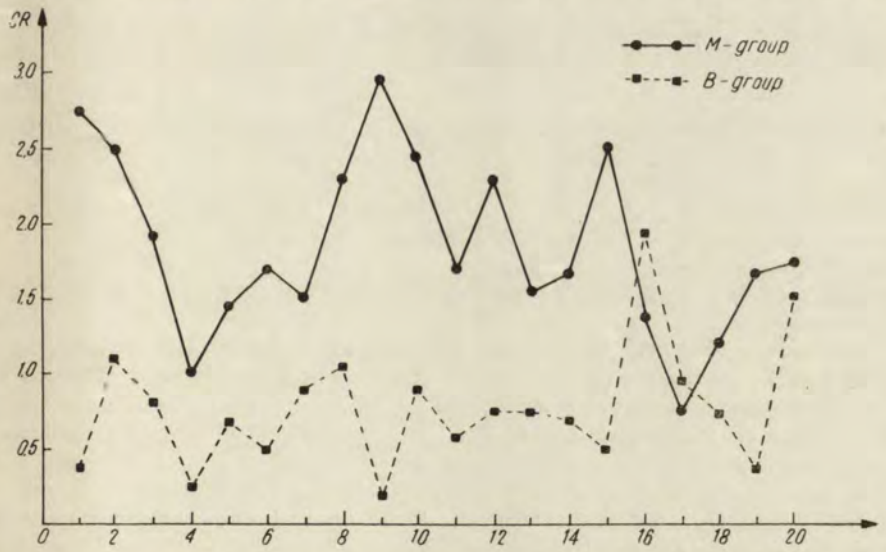

Fig. 1. Average conditioned licking responses in two groups of dogs. Circles = dogs receiving water directly into the mouth (M-group). Squares = dogs drinking from a bowl (B-group). Abscissae: daily sessions. Ordinates: mean number of conditioned responses

($F = 0.93$; analysis of variance, the mixed design I, according to Lindquist 1953) and probably a much larger number of animals would be necessary to neutralize the marked variability within the groups.

Table I shows the results of acute extinction in both groups of animals. The results are also statistically inconclusive, but there is a hint that the fistulated group is more resistant to extinction.

Table I

Extinction of the licking CR in two groups of dogs

B-group Dogs drinking from a bowl		M-group Dogs drinking through a fistula	
Dog	Number of trials to criterion	Dog	Number of trials to criterion
Bezim	28	Hikaru	60*
Kashiwado	20	Hatiko	31
Salus	6	Tatsuo	30
Neptun	5	Masao	5

* Session was ended if the criterion of 4 consecutive trials without response was not reached within 60 trials.

It should be noted that both groups differed in two respects. Different was the way of presenting the US, and, in addition, in one group there was a cheek fistula with inserted injection assembly. Either of these factors might have contributed to the expected superiority of the fistulated dogs. Therefore, instead of repeating the same experiment with other dogs, the second experiment was designed to account for both factors.

EXPERIMENT II

Conditioned licking in milk-conditioned dogs

Material and method. Eight adult mongrel, experimentally naive dogs served as subjects. In all the dogs fistula of the right cheek was surgically prepared and all the animals learnt to drink milk (diluted 1:1 with water) in the same way as did the dogs of the experiment I. The same training procedure was applied to these dogs except for two important changes:

1. All the dogs during all the experimental sessions had the tube and the injection assembly inserted into the cheek fistula and each session started and ended with drinking through the fistula.

2. Each animal was used as its own control. Animals taught to drink from the bowl were consecutively trained with the US (milk) administered through the fistula, and vice versa, the dogs drinking initially the milk through the fistula were afterwards retrained with milk presented in the bowl.

Training started similarly as in the experiment I. After the CS-US interval reached 5 sec, there were 10 sessions during which the CRs were counted. On the 11th session the acute extinction was carried out to the criterion of 4 consecutive trials without response. The session was ended if the criterion was not reached within 40 trials. The dogs were given a 3 day rest and a new series of 10 sessions was started with the other kind of the US (bowl or fistula, resp.). This series of sessions also ended with an extinction session. Mean number of CRs from series of sessions (i.e., 10 days of 4 trials) with bowl-US was compared with the mean CR from sessions with mouth-US.

Results. Three dogs were trained first using milk in a bowl as the US reinforcing the metronome; afterwards the drinking from a bowl was replaced by presenting the milk through the cheek fistula. Fig. 2 shows

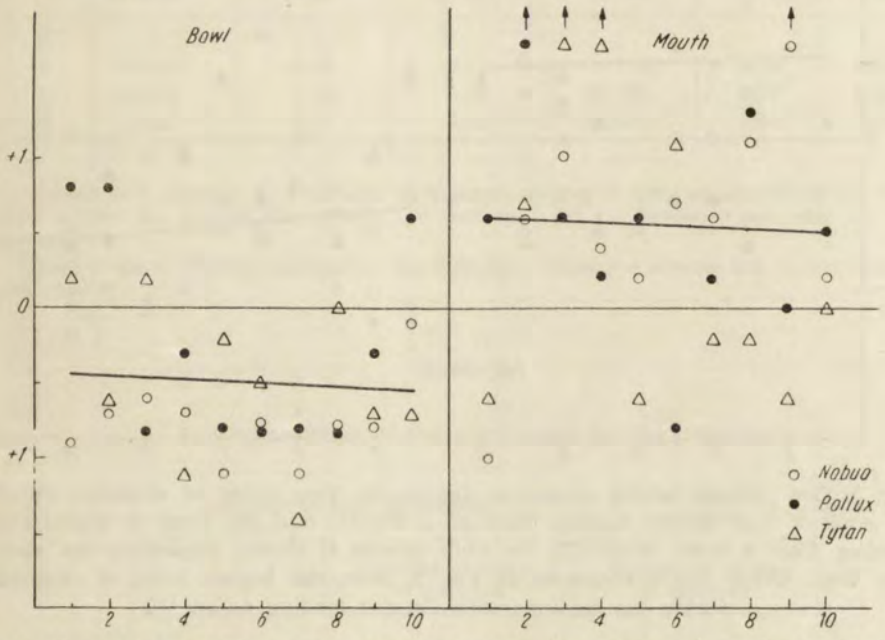

Fig. 2. Conditioned licking responses during the two series of sessions: the first 10 sessions with feeding from a bowl and the next 10 sessions with mouth feeding. Mean CR for each session is shown separately for each of three dogs. Original scores are transformed into z-scores. Abscissae: consecutive sessions. Ordinates: magnitude of CR; a standard deviation calculated separately for each dog is taken as an unit. Regression lines show that there are no definite trends during both series of sessions. Note a much higher performance level during sessions with mouth feeding as an US

the results transormed into z-scores; that means that a mean score for each dog from both series of sessions equals to 0 and the standard deviation (taken as a unit on the ordinates) equals one. There is an evident superiority of responding obtained during the second 10 sessions, i.e., when the milk was injected through the cheek fistula directly into the

mouth. Analysis of the regression during first and second stage of training shows that there are no trends in either series of sessions.

In the five other dogs the training was started with the direct „mouth-feeding" as the US and followed by the sessions with the bowl-feeding. The results are shown on Fig. 3. Here again the superiority of res-

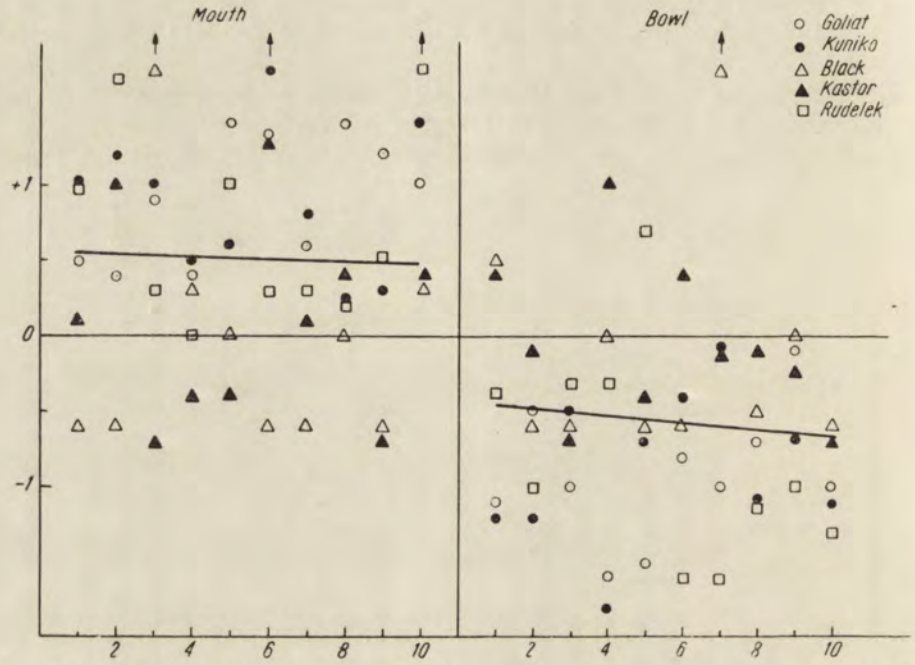

Fig. 3. Conditioned licking responses during the two series of sessions: the first 10 sessions with mouth feeding (through a fistula) and the next 10 sessions with feeding from a bowl. Mean CR for each session is shown separately for each of five dogs. Other explanations as in Fig. 2. Note the higher level of responding during the sessions with fistular feeding as an US

ponding during M-sessions is evident. Since there is no effect of the sequence of these two ways of feeding, the Wilcoxon matched-pairs signed-ranks test (Siegel 1956) was applied to estimate the statistical significance of the difference between M-sessions and B-sessions in all eight dogs. In each dog the performance was better during the M-sessions, so the confidence level is less than 0.01 in a two-tailed test. The results of individual dogs are presented in Table II.

Finally, Table III shows the results of acute extinction. The animals show show greater resistance to extinction after M-sessions. Significance of this result is 0.031 (one-tailed Wilcoxon test; note that here the number of matched pairs is reduced to 5: there is no difference in two dogs and one could not be tested during B-sessions because on infection).

Table II

Comparison of CRs in two series of sessions

	Dog	Average CR during bowl sessions	Average CR during mouth sessions	difference	t	p
Group M-B	Goliat	4.06	8.30	+ 4.24	9.51	0.0001
	Kuniko	1.84	4.50	+ 2.66	8.00	0.0001
	Black	0.20	0.31	+ 0.11	0.48	0.64
	Rudelek	1.77	3.74	+ 1.97	5.41	0.0001
	Kastor	0.26	0.33	+ 0.07	0.12	0.91
Group B-M	Nobuo	0.29	2.17	+ 1.88	6.10	0.0001
	Pollux	0.84	1.05	+ 0.21	0.93	0.36
	Tytan	0.11	0.61	+ 0.50	2.84	0.006

Group M-B received first training with mouth feeding as US and afterwards the feeding from a bowl was applied. Group B-M had first the bowl reinforcement and later the mouth feeding.

Sign + was arbitrarily assigned to the difference when the average CR during M-sessions was greater.

Table III

Acute extinction of the conditioned licking response

	Dog	Extinction after M-sessions: Number of trials to criterion	Extinction after B-sessions: Number of trials to criterion
MB-group	Goliat	39	25
	Kuniko	40*	16
	Black	5	5
	Rudelek	40	40
	Kastor	9	?**
BM-group	Nobuo	40	14
	Pollux	12	9
	Tytan	13	10

* Session was ended if the criterion of 4 consecutive trials without response was not reached within 40 trials.

** The dog Kastor could not be tested after B-sessions because of infection.

DISCUSSION

The above presented results confirm our prediction that introduction of food directly into the mouth is a superior procedure for classical conditioning of consummatory reflexes as compared with the feeding from the bowl. A common sense prediction might be just the opposite, since there is no obvious reason why the „natural" way of eating should not be the most efficient mode of presenting the US. Let us reconsider the premises that led the authors to assuming a more efficient conditioning by the use of the mouth feeding.

The two varietes of inborn reflexes were clearly recognized by Sherrington (1906) who named them „precurrent" and „consummatory" reflexes respectively. Later on, Tinbergen (1951) incorporated a similar concept into his theory of instinctive behavior. The significance of these two types of unconditioned reflexes in conditioning has been recently shown by Sołtysik and Konorski (1966) and Konorski (1967). The latter authors stressed that both drive and consummatory activities can be conditioned, but they may differ in many important details. For example, it is well-known that pairing of an indifferent with a noxious stimulus may result either in a good consummatory defensive CR (leg flexion, eye blink, etc.) when the CS-US interval is short (0.2 — 2.0 sec) or in a fear CR (the so-called conditioned emotional response) if the CS-US interval is of the order of minutes.

In the food conditioning the situation is more complex. First of all, we have but little knowledge of drive (i.e., hunger) conditioning. Moreover, in contradistinction to the noxious stimuli which elicit both drive and consummatory responses, the hunger drive is produced by intraorganismic factors while the consummatory reflexes are elicited by an external object-food acting upon the mouth mucosa. However, some external stimuli such as the sight and smell of food seem also to be potent though possibly conditioned factors eliciting or releasing a hunger drive and the appropriate behavior. Taking all this into account, one has to assume that the usual method of classical food conditioning, i.e., the pairing an indifferent stimulus with the presentation of food, consists of both drive and consummatory conditioning. The neutral stimulus is paired first with the sight and smell of food and this should make it a CS eliciting the hunger reflex. On the overt behavioral side it will be manifested by the looking for, looking at, approaching to and seizing the food. Then, at the moment of gustatory stimulation the consummatory reflexes are initiated, such as salivation, licking, chewing and swallowing. Thus, the future CS is also being paired with the gustatory US and

this transforms it into the CS eliciting the consummatory CR. In other words, the CS becomes a double signal and elicits two distinguishable CRs: a drive CR and a consummatory CR. The final effect depends on the relative strength of those CRs and on the very nature of the mutual relationship between the drive and consummatory reflexes. These two types of activity are, no doubt, antagonistic. There is an obvious necessity to postpone consummatory reflexes while looking for food, and vice versa, the general agitation, locomotor activities and other aspects of the appetitive behavior must be checked during the consummatory act of eating. This may be particularly true for the carnivores who eat large quantities of food between long intervals of rest and drive-instigated behavior.

Therefore, whenever both drive and consummatory CRs occur in response to the same CS, a diminution of either CR should be expected. Konorski and Wyrwicka (1950) have found that when an overtrained CS eliciting a strong salivary (i.e., consummatory) CR was transformed into a signal eliciting an instrumental response rewarded by the same food US, the instrumental CR became weaker than that established to a new stimulus. According to our concept of food instrumental conditioning (Sołtysik 1960) the instrumental movement is preceded and instigated by the drive CR. Thus the „contamination" by the consummatory CR prevented the full occurrence of the instrumental CR in the Konorski and Wyrwicka experiment. This phenomenon was recently reinvestigated by Ellison and Konorski (1966) who also explained it in terms of the antagonism between the drive and consummatory reflexes.

The opposite phenomenon was found in the present study. Direct mouth-feeding eliminated or greatly diminished those properties of food (sight and smell) which enhance the drive reflex, leaving the gustatory stimulation as the main sensory feature of the US. Thus, the CS paired with the fistular feeding was less contaminated with the drive CR than the CS paired with food presented in the bowl. Consecutively, the consummatory CRs were stronger in the former case since there was much less of the drive CR.

SUMMARY

Conditioned responses constituting motor components of an unconditioned consummatory food reflex (licking, mouthing, chewing and swallowing movements) to the gustatory stimuli are easily established when the CS (a metronome) is paired with the direct administration of food into the mouth. The frequency and the resistance to extinction of these CRs is greater than that of the same responses conditioned by presenting

the food in a bowl. These results are explained by the concept of an antagonism between conditioned drive response and conditioned consummatory responses. Using the direct reinforcement and thus omitting the approach reaction and the seizing of food leads to an establishment of a practically pure consummatory response. On the contrary, when the food reinforcement is presented „indirectly" in a bowl, the very moment of reinforcement is preceded by the alimentary drive reflexes like approach, sniffing and seizing the food, and these responses are conditioned along with the consummatory ones, the latter being partially inhibited.

REFERENCES

ELLISON, G. D. and KONORSKI, J. 1966. Salivation and instrumental responding to an instrumental CS pretrained using the classical conditioning paradigm. Acta Biol. Exp. (Warsaw) *26:* 159—165.

KONORSKI, J. 1967. The integrative action of the brain. Univ. Chicago Press, Chicago.

KONORSKI, J. and WYRWICKA, W. 1950. Researches into conditioned reflexes of the second type. 1. Transformation of conditioned reflexes of the first type into conditioned reflexes of the second type. Acta Biol. Exp. (Warsaw) *15:* 193—204.

LINDQUIST, E. F. 1953. Design and analysis of experiments in psychology and education. Houghton Mifflin Co.

SHERRINGTON, C. S. 1906. Integrative action of the nervous system. Yale Univ. Press, New Haven.

SIEGEL, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co, New York.

SOŁTYSIK, S. 1960. On the intercentral connections in the reflex arc of the alimentary conditioned reflex. In: Asratian, E. A. (ed.), Central and peripheral mechanisms of motor activity in animals: collected papers of an internat. Symp., Acad. Sci. USSR, Moscow, p. 58—60.

SOŁTYSIK, S. and KONORSKI, J. 1966. Relations between classical and instrumental conditioning. XVIII Inter. at. Congr. Psychol., Symp. 4. Classical and Instrumental Conditioning. Nauka, Moscow, p. 66—73.

TINBERGEN, N. 1951. The study of instinct. Oxford, London.

Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 11—21, 1968

THE EFFECTS OF ATROPINE ON ALIMENTARY INSTRUMENTAL CONDITIONED REFLEXES IN NORMAL AND PREFRONTAL DOGS

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(Received June 20, 1967)

In spite of a great number of investigations concerning the effects of anticholinergic agents upon the higher nervous activity of animals and man (see Longo 1966) the mechanisms of the action of these drugs are poorly understood. According to Carlton's theory (1963) the cholinergic system in the brain antagonizes another system, which in turn, activates the behavior. The anticholinergic drugs, e.g., atropine or scopolamine, might release the inhibitory conditioned reflexes (CRs), by blocking the transmission in the cholinergic system. As shown in earlier papers from this laboratory (Brutkowski et al. 1956, Ławicka 1957, Szwejkowska et al. 1963) the method of conditioned inhibition, in which the conditioned inhibitor (CI) precedes the conditioned stimulus (CS) for several seconds, is an extremely sensitive test for detecting even very slight disorders of inhibitory (negative) CRs. Therefore this very test was used through-out the present study, which deals with the effects of various doses of atropine on instrumental food to both positive and negative CSs.

EXPERIMENT I

The effect of atropine in normal dogs

Material and methods. The experiments were performed in a regular sound-proof CR chamber on three mongrel dogs, 9—13 kg of weight. The dogs were trained to respond to a buzzer sound by putting their right forelegs on the feeder,

to obtain reward. After the positive CR was established, in some trials the buzzer was preceded by a metronome and this compound was never reinforced by food. When the inhibitory CR to the buzzer following the metronome was developed, the interval between the two stimuli was gradually prolonged up to 6 sec. Finally the inhibitory compound consisted of: the metronome sounding for 5 sec, 6 sec interval, and the buzzer sounding for 5 sec.

Each experimental session consisted of six positive and two negative trials. The intertrial intervals were about 2 min. Experiments were performed daily except for Sundays. Reinforcement consisted of small pieces of bread soaked in broth, so that the total amount of food presented during the sessions did not satiate the animal.

When in ten consecutive inhibitory trials (five sessions) the animals performed no more than one error, the experiments with administration of atropine began. The atropine sessions were conducted at most once a week. The atropine sulphate in physiological solution was injected subcutaneously to a fasting animal and 45 min or 1 hr later the experimental session began. The consecutive sessions were performed every 2 hr till the moment when the CR performance of the animal returned to normal. After the series of sessions with atropine, analogous control series with the injection of physiological salt solution was made.

Results. When a dose of atropine amounting to 0.15 mg/kg was administered, the behavior of the dogs was not changed: they willingly came to the CR chamber, drank water and ate food with apetite, jumped swiftly upon the stand and did not exhibit any motor disorders.

The perceptible changes in their behavior appeared, however, during the experimental session. The dogs were more restless than usually, incessantly shifting from foot to foot. Both full and abortive instrumental responses occasionally appeared during the intertrial intervals.

The instrumental responses to the positive CRs were normal, their latencies remained unchanged. On the other hand, the inhibitory CRs to the buzzer following the metronome (but never to the metronome itself) were disinhibited. This disturbance was manifest in all dogs for about 7 hr (that is, for 4 or 5 successive sessions), and then the CR performance returned to normal. On the following days the experiments ran normally.

The atropine dose 0.25 mg/kg produced more marked disorders. The animals drank water reluctantly. The act of eating was prolonged and small bits of food remained in the bowl. Dog no. 3 was unable to take food during the third post-atropine session.

The restlessness during the experimental sessions was stronger than after the small dose and the intertrial instrumental responses became more frequent. The responses to the positive CSs became occasionally impaired in that the animals made only abortive flexions instead of placing the forelegs on the food-tray. This was particularly clear in dog no. 3 in which the majority of movements were abortive, and in a few trials the instrumental responses were absent. As to the inhibitory CRs, their disorder in the dogs no. 1 and 2 was similar to that after a smaller

dose, whereas in the dog no. 3 it was less pronounced. The period of disturbance lasted for about 9 hr (five sessions).

After the dose of 0.4 mg/kg the most pronounced symptom was a strong impairment of motor acts. The animals walked slowly and akwardly, were not able to jump upon the stand and had clear difficulties in placing the foreleg on the food-tray. They had also difficulties in eating and drinking chiefly because of the impairment of swallowing. All these disorders were particularly strong 3 hr after the injection, so that the dogs no. 2 and 3 were unable to continue the performance during that period.

In spite of this, the motor restlessness during the experimental sessions, manifested by perpetual shifting from foot to foot, was very strong and longlasting. The instrumental responses to the positive CSs were mostly abortive in the dogs no. 1 and 3, whereas they were normal in the dog no. 2. The inhibitory CRs were very strongly disinhibited in the dog no. 2; the dogs no. 1 and 3 were also disinhibited, but their responses to the inhibitory CS were abortive. The disorders lasted for about 11 hr.

The results of these experiments are represented in Fig. 1A, 2A and 3A.

Discussion. Two main behavioral symptoms were manifested after subcutaneous injections of atropine. One of them consisted in the increased motor excitation and the other one in the impairment of motor acts.

After a small dose of the drug only the motor excitement is manifested without any slightest impairment of movements. The animals perform all the skillful movements required (jumping on and off the stand, placing the foreleg on the food-tray), their feeding behavior and locomotion are quite normal. Therefore this very stage of the atropine effect is most interesting for our discussion.

If we look through the Fig. 1, 2 and 3, we may observe that along with the increase of restlessness manifested by the increase of shifting from foot to foot, other striking behavioral changes become apparent. This is the disinhibition of intertrial instrumental responses and disinhibition of inhibitory CRs to the compound stimuli consisting of the conditioned inhibitor and CS. Since we have no reason to assume that atropine produces the increased hunger drive, this disinhibition should be attributed to the arousal of the motor behavioral system (Konorski 1967), i.e. to the final link of the central part of the instrumental CRs. This assumption is in good egreement with the results obtained by Bignami (in prep.) who has found that in the „go-no go" differentiation based on avoidance in rats there was a strong impairment of no-go responses after administration of another anticholinergic drug, namely scopolamine. It is interesting to observe, that in these experiments, similarly to ours,

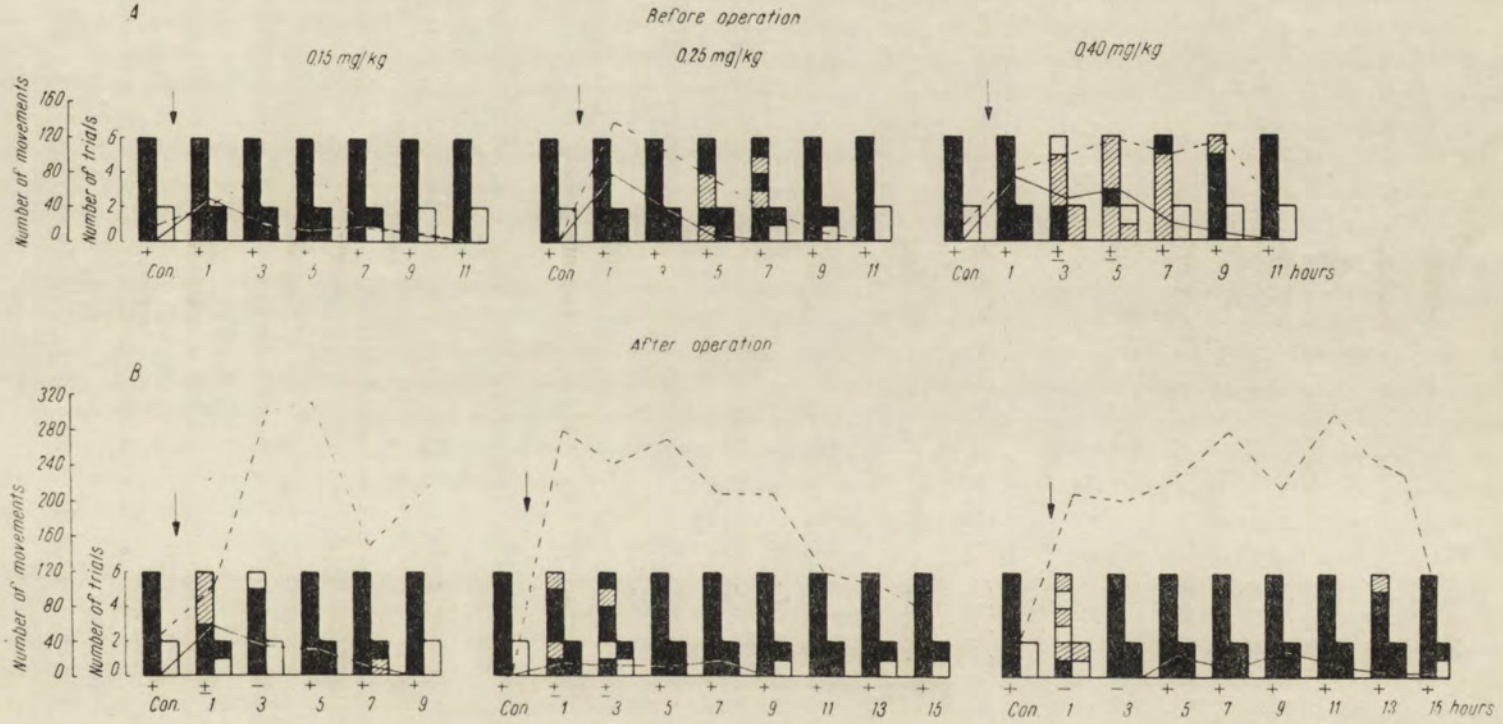

Fig. 1. Effect of atropine on the CR activity in the dog no. 1. A, before operation; B, after operation. Each two column block denotes one session; left column denotes positive trials (six trials); right column denotes negative trials (two trials). Black part of column, presense of instrumental response; hatched part of column, abortive response; white part of column, no response. Continuous lines denote intertrial movements, broken lines denote number of shifting from foot to foot movements. +, acceptance of food; —, refusal of food; ±, partial refusal of food; con, control session; 1, 3, 5, etc., time of censecutive sessions after atropine

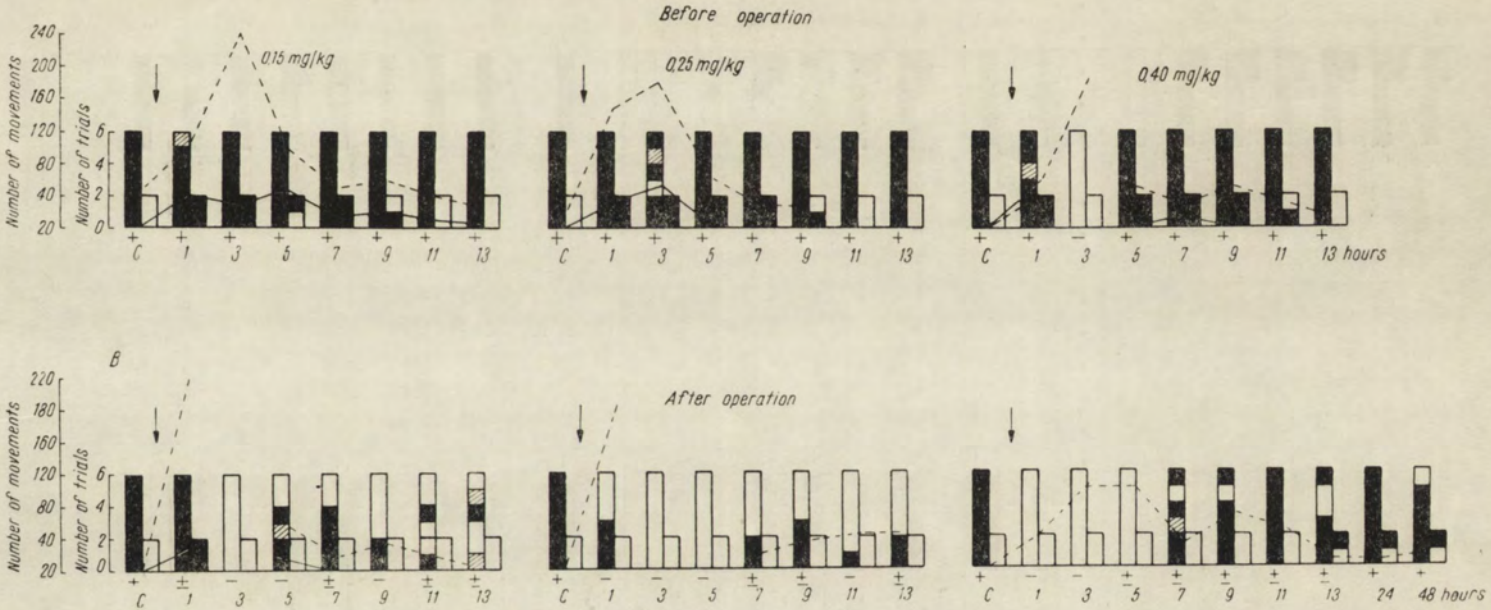

Fig. 2. Effect of atropine on the CR activity in the dog no. 2. Denotations as in Fig. 1

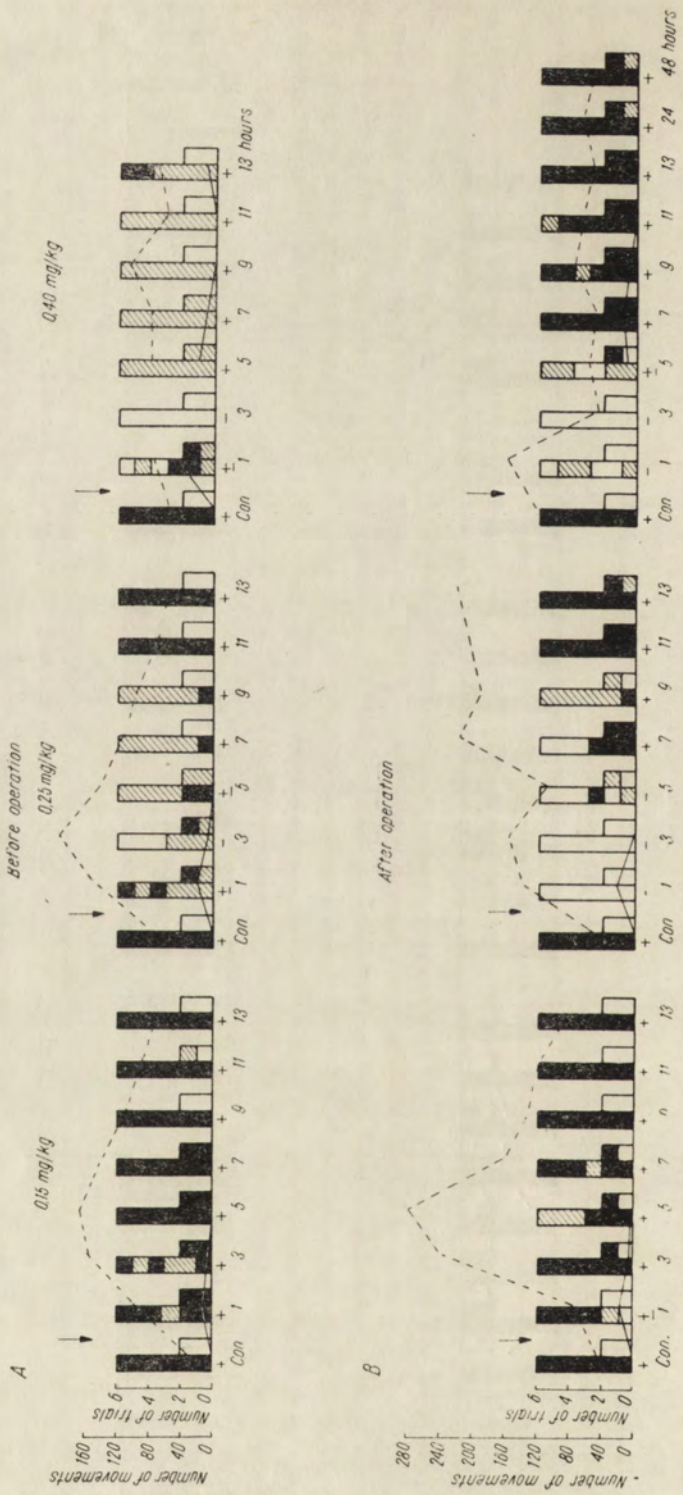

Fig. 3. Effect of atropine on the CR activity in the dog no. 3. Denotations as in Fig. 1

small doses of scopolamine affected chiefly the no-go response whereas larger doses, on the contrary, were detrimental rather to the go responses. Since in the procedure applied by Bignami incorrect responses of both no-go character and go character were punished by an electric shock, we can conclude that the preponderance of go responses over no-go responses after small doses of scopolamine indicate that the disorder is caused by a motor hyperactivity rather than by an increase of the fear drive.

If our interpretation of both ours and Bignami's experimental results is correct, then it can be concluded that disinhibition of instrumental responses can result both from the drive disinhibition produced, for instance, by prefrontal lesions (Szwejkowska 1963), and from the increase of motor excitement. It is interesting to note that if the doses of the drug are increased, then two separate symptoms, seemingly opposite to one another, are produced: on the one hand, there is an evident impairment of the motor acts manifested by the abortive character of the trained responses (e.g., lifting a foreleg without placing it on the food-tray), and, on the other hand, the hypermotility manifested by shifting from foot to foot movements. Disinhibition of the trained movement still remains. Only after the administration of still larger doses, when the animals refuse to take food and are highly paretic, the whole CR activity is abolished. However, even in this state, the instrumental movement of placing the leg on the platform is possible, as shown by Zieliński in experiments with avoidance CRs (Zieliński, unp.).

It is worth mentioning that the disinhibition of the instrumental response was observed only during the operation of the CS following the CI, but never during the operation of the CI itself. An analogous phenomenon was observed also after prefrontal lesions. This is explained by the fact that the CI, as a purely negative CS, in contradistinction to the CS following the CI, does not produce any „readiness" to perform the trained movement. This is another evidence for the postulate that the instrumental response can occur only when its „center" is subliminally activated.

EXPERIMENT II

The effect of atropine in dogs after prefrontal lesions

After it was found that small doses of atropine produce disinhibition of inhibitory instrumental CRs, a symptom very similar to that produced by prefrontal lesions, it was thought useful to administer this drug to dogs which previously sustained this operation. Below is the description of these experiments.

Material and method. The same three dogs which were used in Part I were taken for these experiments. After the testing experiments described in Part I were completed the animals were operated upon. The lesions affected the medial part of the prefrontal area, i. e., that area the ablation of which produces a well pronounced disturbance of conditioned inhibition (Szwejkowska 1963). As seen in Fig. 4, in dog no. 1 the ablation was small including only the lower part of gyrus proreus medialis and dorsal part of area praecruciata medialis. In dogs no. 2 and 3 the lesions were larger and they included the whole gyrus proreus medialis, area genualis, area praegenualis and the significant part of area praecruciata.

After these lesions the negative CRs to the buzzer following the metronome were strongly disinhibited. In dog no. 1 disinhibition lasted for about 15 days, in dogs no. 2 and 3 for about 28 days.

Six weeks after operation, when CR activity was fully compensated, the test

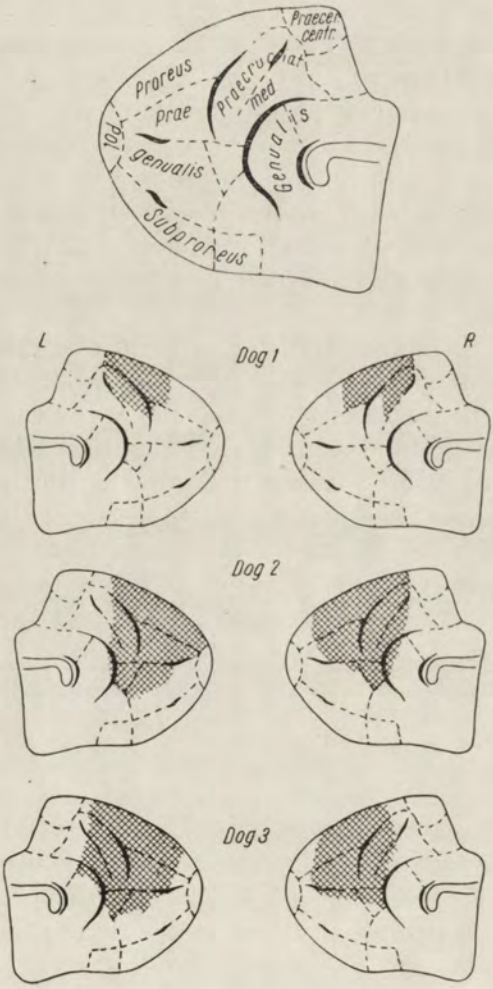

Fig. 4. Extents of medial lesions. Top, map of medial surfaces of the prefrontal region. Below, schemes of myeloarchitectonical areas of the prefrontal cortex with the indications of the placements of the lesions. R, right hemisphere, L, left hemisphere.

experiments with atropine were repeated. They were performed in exactly the same way and by using the same doses as before operation.

After the series of experiments was ended, the brains were fixed by perfusion with a solution of 10% formalin, embedded in paraffin, sectioned and stained by the Klüver method. The extent of lesions, verified by postmortem examination of the brains, is presented in Fig. 4.

Results. When the prefrontal dogs were given the same doses of atropine as before operation, it became immediately apparent that their motor activity was much more strongly affected and lasted for a longer time. The animals were impaired in eating and drinking even after receiving the smallest dose of the drug (0.15 mg/kg). The act of eating was protracted and swallowing became difficult. Drinking became abnormal because the dogs grasped the fluid by mouths instead of using their tongues.

Furthermore the animals displayed strong disorders of vision as manifested by wrong appreciation of distance and direction when jumping on or jumping off the stand. The locomotor behavior was strongly impaired, which was most apparent when the animal went up or down a staircase. Occasionally the muscular tonus was so diminished that the animals were unable to maintain their upright posture on the stand and occasionally lay down. This never occurred before operation.

The disorders of the CR activity in particular animals were the following (Fig. 1B, 2B and 3B):

In dog no. 1 which sustained a less extensive lesion in the prefrontal area than the other dogs, the disorders of eating were less manifested and therefore the test experiments could be performed regularly every two hours. It may be seen from Fig. 1 that the shifting from foot to foot movements were still more intense than before operation and disinhibition was even more pronounced, lasting up to 15 hr after the large doses of atropine.

In dog no. 2 the test experiments were greatly disturbed by the refusal of taking food and the general motor disorders. Therefore the picture of areflexia or hyporeflexia prevailed and, as a consequence, disinhibition was poorly manifested.

In dog no. 3 in some test experiments there was refusal of taking food and total areflexia, in others, when the positive CRs were present a strong and longlasting disinhibition was manifest.

Discussion. The main results of this series of experiments was the increased sensitivity of the prefrontal animals to atropine. We cannot find any satisfactory explanation of this finding and we must leave this question open to further investigation.

As far as the symptom of disinhibition of inhibitory CRs is concerned, it was masked by general deterioration of the animals' motor activity.

However, in those cases in which this deterioration was not present it seemed that disinhibition of inhibitory CRs was more longlasting than in normal dogs. Accordingly, we may see here a summation of the effect of prefrontal lesion with that of the atropine.

It should be mentioned that although after prefrontal lesion the effect of atropine upon motor activity was much increased, it was certainly prone to habituation. In fact, in all our dogs the third administration of this drug, although the dose was higher, it did not produce stronger disorders than the previous administration, but, on the contrary, its effect on the animals' general motor activity seemed to be attenuated. This shows that the prefrontal lesion does not affect the process of habituation to the action of atropine.

SUMMARY

1. The present study was concerned with the effects of subcutaneous administration of atropine upon alimentary instrumental CRs and general behavior of dogs.

2. The dose of 0.15 mg/kg produced an increased motor excitation manifested by an incessant shifting from foot to foot during the experimental session. The instrumental response (placing the right foreleg on the feeder) to the positive CS remained unchanged, but the inhibitory CRs were dramatically disinhibited. The effect of atropine lasted for about 7—9 hr.

3. The dose of 0.25 mg/kg produced some disorders in skillful movements, in food intake and drinking. The motor excitement was still increased, but the instrumental responses were sometimes reduced to mere flexion of the leg without placing it on the feeder. Disinhibition of inhibitory CRs was the same as with the smaller dose. The effect of atropine lasted for about 9 hr.

4. The dose of 0.4 mg/kg produced even more pronounced and long-lasting disorders of motor activity with total refusal to take food and drink water. Disinhibition (after the return of CR activity) lasted for about 5—11 hr.

5. After prefrontal lesions the tolerance to atropine was dramatically diminished: the dose of 0.15 mg/kg produced already the pronounced impairment of motor activity, and the disorders of positive and inhibitory CRs after the injection were more marked and long-lasting than before operation. The extent of lesions seemed to play a role in the decrease of the tolerance to atropine.

6. The probable mechanism of the effect of atropine upon the CR activity is discussed.

REFERENCES

BRUTKOWSKI, S., KONORSKI, J., ŁAWICKA, W., STĘPIEŃ, I. and STĘPIEŃ, L. 1956. The effect of the removal of frontal poles of the cerebral cortex on motor conditioned reflexes. Acta Biol. Exp. (Warsaw) *17:* 167—188.

CARLTON, P. L. 1963. Cholinergic mechanisms in the control of behavior by the brain. Psychol. Rev. *70:* 19—39.

KONORSKI, J. 1967. Integrative activity of the brain. Univ. Chicago Press, Chicago.

LONGO, V. G. 1966. Mechanisms of the behavioral and electroencephalografic effects of atropine and related compounds. Pharm. Rev. 18.

ŁAWICKA, W. 1957. The effect of the prefrontal lobectomy on the vocal conditioned reflexes in dogs. Acta Biol. Exp. (Warsaw) *17:* 317—325.

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. (Warsaw) *23:* 181—192.

Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 23—34, 1968

INHIBITION AND FACILITATION OF ALIMENTARY BEHAVIOR ELICITED BY STIMULATION OF AMYGDALA IN THE CAT

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(Received June 2, 1967)

In the previous paper it has been shown that, depending on the lesion of particular nuclei of the amygdaloid complex in cat, it was possible to elicit specific changes in the quantitative and qualitative control of the food intake (Lewińska 1967a). Bilateral lesions of the ventral part, which mostly included the nucleus basalis parvocellularis (Abp), evoked a hyperphagia and an increase of the milk intake. On the other hand, as a result of lesions of anteromedial regions, partly including the Abp, the nucleus corticalis and medialis (Aco and Am), as well as the anterior amygdaloid area (Aa), the milk intake was reduced and there was usually a general hypophagia and frequently a temporary aphagia in relation to a raw meat.

The aim af the present work was to study the effect of electrical stimulation of these regions of brain on both the conditioned and unconditioned alimentary behavior in the cat.

MATERIAL AND METHOD

Experiments were performed on 32 adult cats of both sexes. The alimentary instrumental CR, which consisted in putting the right forepaw on the food-tray, has been established in the animals placed in an experimental cage. The sound of a bell was the CS. The CS was reinforced with a piece of raw horse meat. Daily experimental sessions consisted of 20 trials each. Intervals between trials were irregular, between 30 sec and 2 min. After each experimental session cats were fed ad libitum with milk and cereal containing boiled meat. When during 10 successive experimental sessions cats correctly responded to each CS, amygdalar electrodes were

implanted according to a slightly modified Delgado's (1955) method. Operations were performed under Nembutal anaesthesia (40 mg/kg). A detailed description of the procedure of implantation has been given in the previous paper (Lewińska and Romaniuk 1966). Coordinates for electrodes placement were based on the Jasper and Ajmone-Marsan (1954) atlas. Four electrodes were symmetrically introduced into the following regions of the amygdala: the posterior, medial and anterior parts of Abp and the Aco/Am. In five cats, electrodes were also implanted in the lateral nucleus (Al) and in the nucleus basalis magnocellularis (Abm).

The CR experiments were resumed within a week after the surgery. The stimulation of the amygdala during the CR sessions started two weeks later. Rectangular pulses having the frequency of 50 c/sec width of 0.1 and 10 msec and 0.1 to 2.0 mA amplitude, monitored on the screen of a cathode ray oscillograph, were used for stimulation. The current was switched on, either 5 sec before the presentation of a CS, or during the CR performance, or during eating. Stimulation continuing for 5 to 15 sec, was applied about ten times during a single experimental session.

The first stimulation was of a preliminary testing character and was applied in the absence of the CS or feeding. Its aim was to determine the threshold and type of autonomic and/or somatic reactions which could de obtained by the use of a given electrode. During subsequent experiments, stimulation was applied with a current of sub-threshold strength and its effect on the conditioned and unconditioned alimentary behavior was examined. Experiments with the stimulation were performed on each cat at intervals of a few days.

After completing of an experimental series, the points under study were coagulated for 15 sec with a 3 mA current. After a lapse of about a month, cats were sacrificed and their brains perfused with a 10% formalin. Paraffin sections 20 μ thick were sectioned in the frontal plane. Every tenth of them was stained by means of Nissl's method. An actual localization of electrodes wes established by assuming that the stimulated point was in the middle of a lesion.

RESULTS

Within the first two weeks after the surgery, it was found that the implantation alone exerted a certain influence on the alimentary behavior of the animals. A decrease in the milk intake was observed in cats with electrodes implanted in the Abp. Some cats of this group refused to eat raw meat for a few days after the operation and, thereafter, ate it reluctantly. In a few cases, the process of eating was slowed down, mainly due to the prolongation of the period of chewing. The irritating effect of electrodes implanted in the anteromedial regions was different. Cats with such implantations either behaved similarly as prior to the surgery, or displayed a greater excitement when eating raw meat. A slight increase in the milk intake was observed in a few cats of this group.

These preliminary observations, concerning the division of amygdala into the zones, facilitatory and inhibitory in respect to the alimentary responses was confirmed by the experiments with electrical stimulation. The distribution of the alimentary responses, elicited by the electrical stimulation of the amygdala is shown in Fig. 1 (Fr. 9.5—14.5).

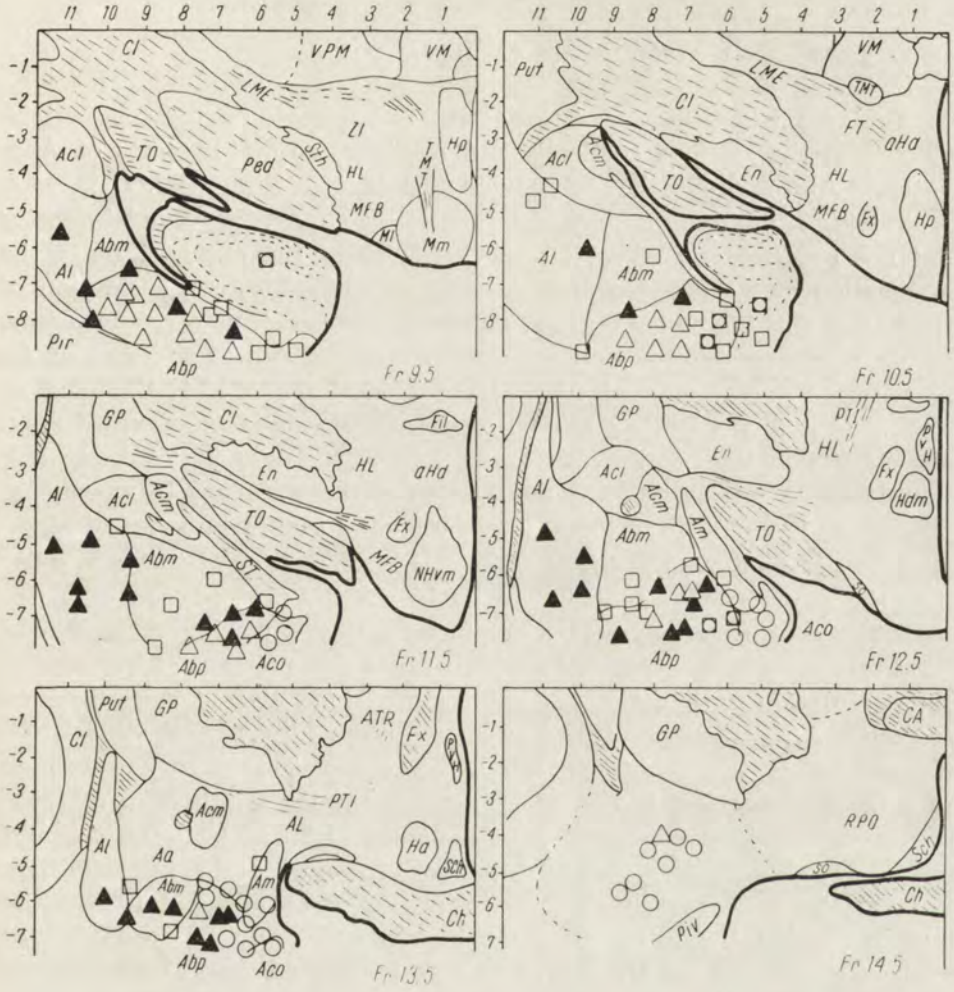

Fig. 1. Series of frontal sections in caudo-rostral direction through the amygdala in cats. Sites of electrodes are indicated from which facilitation and inhibition of alimentary reflexes were obtained. Note, that stimulation of some points gives antagonistic effects. Abbrevations: Abp, nucleus amygdaloideus basalis, pars parvocellularis; Abm, n. amygdaloideus basalis, pars magnocellularis; Aco, n. amygdaloideus corticalis; Am, n. amygdaloideus medialis; Al, n. amygdaloideus lateralis; Acl, n. amygdaloideus centralis (pars lateralis); Acm, n. amygdaloideus centralis (pars medialis); Aa, area amygdaloidea anterior; Pir, lobus piriformis; ST, stria terminalis

I. ALIMENTARY FACILITATORY SYSTEM

The area which produced the facilitatory effects on the food intake comprised the nucleus corticalis and medialis, adjoining parts of Abp, anterior Abp and anterior amygdalar area (Aa) — Fig. 1, Fr. 11.5—14.5.

Testing stimulation. The stimulation with a current of 0.5 mA intensity did not produce any effect on the behavior of the animals. After the application of a somewhat stronger current (0.6—1.0 mA), a reaction of searching, sniffing or licking was obtained from some points. The points, which produced this reaction were mostly distributed in the area of Aa and in the dorsal part of Abp in the frontal plane 13.5. Chewing or contractions of the ipsilateral part of the muzzle could be obtained from other parts in the frontal planes 13.5 and 12.5. Turns of the body and jumping back occurred to the stimulation at the boundary between Aco, hippocampus and stria terminalis in the frontal planes 11.5 and 12.5.

Stimulation during the food CR session. Regardless of the fact, whether the stimulation was switched on before the presentation of a CS, during the performance of a CR or during eating, a marked increase was obtained in the alimentary excitation. After a few pairings of the electrical stimulation with a CS, the stimulation alone evoked a conditioned response. After the application of an optimum intensity of stimulation (0.3 to 0.5 mA), the conditioned motor response was repeatedly performed to a CS and, besides, it was more violent. On the stimulation of some points, especially those in the frontal planes 11.5 and 12.5, the cats did not take food as usually, that is, directly with their mouths, but they took it from the food-tray using their ipsilateral paws and put it into the mouth. During the intervals, after having eaten the food, instead of waiting as usually for the next CS, cats performed several conditioned responses. With the increase in the alimentary excitation, these movements turned into scratching of the food-tray and the process of eating was sped up. After eating up of the meat, cats frequently smelled at the empty bowl, licked it and, sometimes, even tried to take out the meat from the next bowl, covered by the cover of the food-tray. Among other activities cats jumped on the food-tray, pulled as it, bit and tried to reach the food.

The stimulation of some points, situated on the boundary of the facilitatory zone, evoked — in addition to the proper alimentary reaction — also different side-effects. These effects, although hampering the performance of the conditioned reaction, did not decrease the alimentary excitation. Thus, for instance, on the boundary of Aco, hippocampus and stria terminalis the points were located which evoked the turns of the body

and backward jumps, referred to above. In such cases, cats performed the conditioned responses and, at the same time, overcame these additionally produced motor reactions. The following may serve as an instant. The stimulation was switched on prior to the presentation of the CS. The cat immediately reached its paw to take the food and, at the same time, bent its body backwards, withdraw its head and slight contractions of its muzzle were observed. Despite these movements, the animal, with its head withdrawn and blindly pawing through the bowl, took out the meat, put it into the mouth and promptly ate up. After the stimulation, the cats ate their food with an increased excitement and, in the intervals, performed several alimentary CRs.

After a few sessions, during which the facilitatory area was stimulated, the experimental situation alone sufficed to produce a strong disinhibition of the conditioned motor reaction. On placing them in the cage, cats started to scratch the food-tray. These symptoms were mitigated by feeding the animals prior to the experimental sessions. However, even in satiated animals, the symptoms of alimentary excitation were evoked by a repeated stimulation of the amygdala.

II. INTRINSIC INHIBITORY SYSTEM

The inhibitory zone included the remaining area of the Abp. Similar properties were also displayed by the points in Abm and Al we examined. The inhibitory zone was non-uniform with regard to the responses, produced by the checking stimulation and the inhibitory effect on alimentary reactions. Of many mixed reactions, the following two types of „pure" inhibitory effects were distinguished: (a) inhibitory effects which were accompanied by the symptoms of aversion towards food and (b) inhibitory effects with the symptoms of an indifferent attitude towards food.

(a) Inhibitory effects with symptoms of aversion towards food

The points from which the reactions, referred to above, could be obtained, were rather scattered. The smallest concentration was recorded in the posterior part of Abp. Similar symptoms were produced by stimulation of almost all points in Al and some in Abm, in particular in its anterior part (Fig. 1, Fr. 9.5—14.5).

Testing stimulation. Gnawing, chewing, abundant salivation, ejecting of the tongue, vomitive reaction, licking and ipsilateral contractions of the mouth were the most frequently observed symptoms when the stimulation was applied with a 0.2 to 0.5 mA current. Depending on the

point and intensity of stimulation, these reactions occurred separately or together and in a definite order. A wide opening of the mouth was observed as a response to the stimulation of some points. Reactions of attention, searching and sniffing about, accompanied by panting, were produced from the points, located in Al and in the narrower part of Abp in the frontal plane 11.5.

Stimulation during the food CR sessions. In many cases, the threshold of inhibition of alimentary reactions was very near the threshold of reactions, observed during the testing stimulation.

Stimulation of many points evoked a reaction which might be termed as an aversion towards food. The motor CR was not always inhibited by a slight (0.1 mA) stimulation. In such cases, however, no reaction of eating was ever brought about. The cat carefully sniffed the food, wrinkling his mouth and shuddering. The CR was inhibited by a stronger or more frequent stimulation. When a slight stimulation was applied after the performance of the instrumental CR, sometimes the cat sniffed and licked the food, now and then reluctantly took it into the mouth but immediately let it slip. Stimulation during eating inhibited the chewing movements and the cat spat out the food. Frequently, the animal violently shook its head so that the meat fell out from its mouth. A stronger stimulation caused the ejection of the tongue. A vomitive reaction and abundant salivation was often brought about but real vomiting was never observed.

On stronger stimulation, many points produced the reaction of gnawing which consisted in abnormal spastic movements of the jaws during which the food, if held in the mouth, fell out and an abundant salivation occurred. Such gnawing movements frequently finished with opening of the mouth and ejection of the tongue.

Inhibitory reactions were marked by a prolonged after-effect. The inhibitory after-effect of the order of a few to about fifteen min was obtained from points situated in anterior and posterior part of Abp as well as from points in Al contained between the frontal planes 10.5 and 13.5. The inhibitory after-effect which occurred after the stimulation of all other points did not exceed 30 sec. During the inhibitory after-effect, the cats sniffed, licked the meat and, finally, began to eat slowly and cautiously, while the morsels were shifted from one side of the mouth to another.

(b) Inhibitory effects with symptoms of an indifferent attitude towards food

Inhibitory points were localized in frontal planes from 9.5 to 12.5 (Fig. 1).

Testing stimulation. The stimulation with the current of 0.1 to 1.0 mA,

mostly evoked no observable effect on the animals behavior. Cats leisurely walked around the cage, sometimes rubbed their sides against the walls and sometimes lay down and remained calm. A stronger stimulation of certain points, located near the zone of defensive reactions, produced lurking, attention, looking about, protesting mewing and, sometimes, urination. Locomotor activities or other somatic reactions were also elicited by a stronger stimulation of other points, situated in the frontal area 9.5.

Stimulation during the food CR sessions. Stimulation with the current of about 0.4 mA evoked — regardless of the moment when it was switched on — an inhibitory effect. Cats did not perform the CR or they stopped eating, let the food slip and mostly withdrew from the food tray, behaving in a similar manner as during the testing stimulation. They responded normally to all auditory, visual and tactile stimuli. When stroked, they fawned and rubbed against the experimenter.

Durnig the stimulation of the points situated in the frontal planes 10.5 and 11.5 of the central area, the inhibitory after-effect was on the whole brief whereas a few minutes' long inhibitory after-effect was produced by the stimulation of the points, situated in the frontal plane 9.5.

After a few experimental sessions, the behavior of the cats in the cage, was subject to certain changes. They became lazy, ate slowly and reluctantly. The latency of the alimentary instrumental CR became prolonged.

III. EXTRINSIC INHIBITORY SYSTEM

The stimulation of the points situated on the boundary of the posterior Abp, hippocampus and stria terminalis, as well as those situated on the boundary of Abp, hippocampus and the cortex piriformis, evoked the reaction of anger. The reaction of fear was obtained from some points in the Abm and dorsal part of the Al. The stimulation with a subthreshold (in relation to the emotional response) current did not inhibit the alimentary reaction. The inhibition of this reaction occurred however, when the emotional responses became manifest, often in the same time as the reaction of attention appeared usually preceding both anger and fear responses. If the stimulation was applied during eating, the meat was usually kept in the mouth even when the cat snarled. It ate it, however, only after the period of the inhibitory after-effect. The inhibitory after-effect was, in general, not long, but it was longer after the symptoms of fear than after the symptoms of anger.

The inhibition of alimentary reactions also occurred simultaneously with the occurrence of different motor reactions and epilepsy which were obtained during the stimulation with a current about 0.4 mA, from the

boundaries of Abp and hippocampus, Al, Abp and Abm, as well as Abp and Abm. Frequently a loud, shrill cry was produced by the stimulation at the boundary of Abp and hippocampus.

After the stimulation the inhibitory effect passed off almost immediately and the cats responded normally to both the CS and the food presentation.

DISCUSSION

The results of the electrical stimulation of the ventral part of the amygdaloid nucleus in the cat, confirmed our previous suggestion (Lewińska 1967a) that this area contains the inhibitory and facilitatory systems for the alimentary behavior. The facilitatory system was localized in the anteromedial area, partly including the Abp and Am nuclei, the Aco and the anterior amygdaloid area. The inhibitory system was localized in the ventrolateral area of which the Abp was most accurately examined.

A large number of contradictory data, concerning changes that occur in the alimentary behavior as a result of the stimulation or lesions of the amygdaloid complex can be noted in the literature of the subject. The divergences of results are often explained by differences in species and different age of experimental animals (Koikegami et al. 1958, Kling and Schwartz 1961, Schwartz and Kling 1964). Contradictory results are often obtained, however, in the experiments on adult animals of the same species. After extensive lesions of the amygdaloid nucleus in the rat, some authors did not observe any essential changes in the alimentary behavior (Anand and Brobeck 1952), whereas some others found aphagia and adipsia (Yamada and Greer 1960, Ward 1961) and still others — hyperphagia and hyperdipsia (Grossman and Grossman 1963). Following the amygdalectomy in cats, the anorexia was recorded by Kling et al. (1960) and hyperphagia by Green et al. (1957) and by Morgane and Kosman (1959). It was also either hyperphagia (Pribram and Bagshaw 1953, Fuller et al. 1957), or aphagia (Brutkowski et al. 1962) that were evoked by the amygdalotomy in other animals. These discrepancies are probably caused by the differences in the location and extent of lesions and, at the same time, by treating the entire amygdaloid complex as a neurophysiological unit.

Similar differencies were observed among the symptoms evoked by stimulation of the amygdala. According to most authors, the stimulation of the amygdaloid nucleus inhibits the alimentary reactions (Fonberg and Delgado 1961, Grossman and Grossman 1963, Norris 1963). On the other hand, stimulating the amygdaloid nucleus in monkeys, Robinson and Mishkin (1961) evoked the food and water intake.

According to a concept put forward by Konorski (1967), in the amygdala (which is the part of what Papez 1937, denoted as the emotive brain), just as in the hypothalamus, there are two reciprocally related centers regulating the alimentary activity of the animals, referred to as the hunger drive center and the hunger anti-drive center. This author assumes that, whereas the hypothalamic alimentary centers control the unconditioned reflexes involved in hunger and satiation, the centers in the amygdala are mainly concerned with the corresponding conditioned reflexes. Similar concepts were also advanced by other authors (Gloor 1960, Goddard 1964, Douglas et al. 1966).

The results obtained by us, using the methods of electrocoagulation (Lewińska 1967a), as well as of electrical stimulation, allowed us to localize the facilitatory and inhibitory systems of the alimentary behavior in the ventral part of amygdala. The picture thus obtained corresponds to the functional reciprocity of alimentary centers as suggested by Konorski (1967). The functional reciprocity of the two systems concerned the quantitative and qualitative control of the food intake, as well as the conditioned motor behavior. An increase of the food intake, evoked by the lesions of the inhibitory (Lewińska 1967a) and stimulation of the facilitatory area (Lewińska 1968) was not conspicuous but significant. Likewise, the stimulation of the inhibitory area did not inhibit hunger, to any drastic extent, and the lesions of the facilitatory area did not result in a persistent aphagia. On the other hand, a differential effect on the appetite was exerted by both the lesions and stimulation of the structures, referred to above. It should be emphasized that the simple instrumental reflex elaborated in the cats was mostly preserved after the lesions of amygdala (Lewińska, in preparation). However, the conditioned behavior was subject to considerable modulation, being intensified during hyperphagia and diminished with hypophagia.

Depending on the point stimulated and on the intensity of stimulation, different forms of behavior were obtained from the inhibitory area. Extrinsic effects, as alimentarly non-specific, are not the subject of our study. On the other hand, we distinguished two forms of the intrinsic inhibition. In one case, cats refused to eat and displayed symptoms of a complete indifference towards food. A similar behavior was recorded in satiated cats. An identical picture of behavior during the stimulation of amygdala was observed by Fonberg and Delgado (1961). In face of the lack of any other symptoms, except for a visible state of comfort, one might suppose that precisely this state of satisfaction, predominating over the hunger drive, inhibits the interest in food. A specifically alimentary character of this inhibition is, however, indicated by the fact that the stimulation and even the implantation alone selectively decreased the daily

food intake and the lesions of the same points led to hyperphagia. Debatable might be only the question whether the inhibition is caused by the state similar to that of satiety or by the appearance of some conditioned reflexes, related to the refusal to eat.

Another form of inhibition, accompanied by distinct symptoms of the aversion towards food, indicates that the inhibitory system of amygdala is provided with other mechanisms which serve the refusal to eat. On the basis of the behavior of the animals, displayed during the stimulation of the points, referred to above, the state of satiety may be excluded as a cause of inhibition. The occurrence of such reactions as, sniffing at the food and even attempts to eat testified against such a possibility. Finally, food was always rejected by the animals as if it was not fit for eating.

This second form of inhibition of the food intake may be easily explained by extrapolating Konorski's views on the correlation between the emotive system and protopathic aspects of external stimuli (Konorski 1967). It may be assumed that protopathic aspects of olfactory stimuli, just like protopathic aspects of gustatory stimuli, are represented in the amygdala and their role is to control the food intake along with the taste stimuli. Accordingly, by the stimulation of individual points in the facilitatory hunger center the olfactory units representing the attractive aspects of the smell of food are activated and hence the animals sniff the food with obvious satisfaction, thus increasing their hunger drive. On the contrary, the stimulation of some points in the inhibitory hunger center produced a distinct aversive response to the food sniffed. Probably, the phenomenon of aversion we observed was similar to that occurring with the overeating with some food when its smell itself spoils the appetite and even evoked nausea. It should be emphasized that the nauseous reaction, passing into vomiting reaction, is often evoked from the same points when they are more strongly stimulated.

Both systems, related to the protopathic properties of stimuli, displayed a considerable degree of reciprocity. Thus, for instance, the aversion towards meat was expressed even in a temporary aphagia both during the stimulation of the negative and after the lesion of the positive emotive system (Lewińska 1967a). On the other hand, the lesion of the former and stimulation of the latter system produced an opposite effect, that is, an increase of the appetite for raw meat.

This differentiation of the inhibitory function of amygdala confirms the considerable importance of this structure for the processes of adaptation.

It is of interest that in contradistinction to the authors who claimed to have found a satiety center within the nucleus of the ventromedial hypothalamus in rats (Anand and Brobeck 1951), rabbits (Balińska 1963)

and goats (Wyrwicka and Dobrzecka 1960), we did not succeed in finding an analogous inhibitory center within the hypothalamus of the cat. The inhibition of the alimentary reaction during the stimulation of the NHvm and adjoining regions was elicited either by the reaction of attention preceding the reaction of aggression, or by the reaction of fear, evoked by the stimulation of the points of flight (Lewińska and Romaniuk 1966). The lesions of the NHvm and adjoining regions mostly produced a considerable increase in the milk intake, combined with a conspicuous polyuria and simultaneous decrease in the solid food intake, accompanied by a drop of the body weight. Equally frequent was the hypophagia without the polydipsia, whereas it was only in a few cases that a certain increase was obtained in the food intake. In addition, this increase was brief and did not lead to obesity (Lewińska 1967b). Maybe, the anatomical organization of the satiety center in the Carnivora is different than that in the Herbivora.

SUMMARY

During the alimentary CR experiments the ventral part of amygdala was electrically stimulated in 32 cats. The following two systems, reciprocally correlated with each other, were distinguished: (a) the system facilitating the alimentary behavior, situated in the anteromedial part (Aco with an adjoining part of Am and Abp, anterior Abp and Aa) and (b) the inhibiting system, situated in the basolateral part.

The author would like to express her gratitude to Professor Jerzy Konorski for his interest in this work, many discussions and a valuable criticism.

REFERENCES

ANAND, B. K. and BROBECK, J. R. 1951. Hypothalamic control of food intake in rats and cats. Yale J. Biol. Med. *24:* 123—140.

ANAND, B. K. and BROBECK, J. R. 1952. Food intake and spontaneous activity of rats with lesions in the amygdaloid nuclei. J. Neurophysiol. *15:* 421—430.

BALIŃSKA, H. 1963. Food preference and conditioned reflex type II activity in dynamic hyperphagic rabbits. Acta Biol. Exp. (Warsaw) *23:* 33—44.

BRUTKOWSKI, S., FONBERG, E., KREINER, J., MEMPEL, E. and SYCHOWA, B. 1962. Aphagia and adipsia in a dog with bilateral complete lesions of the amygdaloid complex. Acta Biol. Exp. (Warsaw) *22:* 43—50.

DOUGLAS, R. J. and PRIBRAM, K. H. 1966. Learning and limbic lesions. Neuropsychol. *4:* 197—220.

DELGADO, J. M. R. 1955. Cerebral structures involved in transmission and elaboration of noxious stimulation. J. Neurophysiol. *18:* 261—275.

FONBERG, E. and DELGADO, J. M. R. 1961. Avoidance and alimentary reactions during amygdala stimulation. J. Neurophysiol. *24:* 651—664.

FULLER, J. L., ROSVOLD, H. E. and PRIBRAM, K. H. 1957. The effect on affective and cognitive behavior in the dog of lesions of the pyriform-amygdala-hippocampal complex. J. Comp. Physiol. Psychol. *50:* 89—96.

GLOOR, P. 1960. Amygdala. In: Field, J. (ed.), Handbook of Physiology, vol. 2, Amer. Physiol. Soc., Washington, p. 1395—1420.

GODDARD, G. V. 1964. Amygdaloid stimulation and learning in the rat. J. Comp. Physiol. Psychol. *58:* 23—30.

GREEN, J. D., CLEMENTE, C. D. and de GROOT, J. 1957. Rhinencephalic lesions and behavior in cats. J. Comp. Neurol. *108:* 505—546.

GROSSMAN, S. P. and GROSSMAN, L. 1963. Food and water intake following lesions or electrical stimulation of the amygdala. Amer. J. Physiol. *205:* 761—765

JASPER, H. H. and AJMONE-MARSAN, C. 1954. A stereotaxic atlas of the diencephalon of the cat. Nat. Res. Council of Canada, Ottawa.

KLING, A., ORBACH, J., SCHWARTZ, N. B. and TOWNE, J. C. 1960. Injury to the limbic system and associated structures in cats. Arch. Gen. Psychiat. *3:* 391—420.

KLING, A. and SCHWARTZ, N. B. 1961. Effect of amygdalectomy on feeding in infant and adult animals. Fed. Proc. *20:* 335.

KOIKEGAMI, H., FUSE, S., HIROKI, S., KAZAMI, T. and KAGEYAMA, Y. 1958. On the inhibitory effect upon the growth of infant animals or on the obesity in adult cat induced by bilateral destruction of the amygdaloid nuclear region. Fol. Psychiat. Neurol. Jap. *12:* 207—223.

KONORSKI, J. 1967. Integrative activity of the brain. Univ. Chicago Press, Chicago.

LEWIŃSKA, M. K. and ROMANIUK, A. 1966. Is the ventromedial nucleus of the hypothalamus a „satiation center"? Acta Biol. Exp. (Warsaw) *26:* 285—297.

LEWIŃSKA, M. K. 1967a. Changes in eating and drinking produced by partial amygdalar lesions in cat. Bull. Acad. Pol. Sci., Sér. sci. biol. *15:* 301—305.

LEWIŃSKA, M. K. 1967b. Ventromedial hypothalamus: participation in control of food intake and functional connections with ventral amygdala. Acta Biol. Exp. (Warsaw) *27:* 297—302.

LEWIŃSKA, M. K. 1968. The effect of amygdaloid stimulation on daily food intake in cat. Acta Biol. Exp. (Warsaw) *28.*

MORGANE, P. J. and KOSMAN, A. J. 1959. A rhinencephalic feeding center in the cat. Amer. J. Physiol. *197:* 158—162.

NORRIS, F. H. 1963. Arrest of activity by temporal lobe stimulation. Neurology *13:* 895—898.

PAPEZ, J. W. 1937. A proposed mechanism of emotion. Arch. Neurol. Psychiat. *38:* 725—744.

PRIBRAM, K. H. and BAGSHAW, M. 1953. Further analysis of the temporal lobe syndrome utilizing frontotemporal ablations. J. Comp. Neurol. *99:* 347—375.

ROBINSON, B. W. and MISHKIN, M. 1961. Alimentary responses evoked from extrahypothalamic structures in Macaca mulatta. Fed. Proc. *20:* 327.

SCHWARTZ, N. B. and KLING, A. 1964. The effect of amygdaloid lesions on feeding, grooming and reproduction in rats. Acta Neurovegetativa *26:* 12—34.

WARD, H. P. 1961. Tegmental self-stimulation after amygdaloid ablation. Arch. Neurol. *4:* 657—659.

WYRWICKA, W. and DOBRZECKA, C. 1960. Relationship between feeding and satiation centers of the hypothalamus. Science *138:* 805—806.

YAMADA, T. and GREER, M. A. 1960. The effect of bilateral ablation of the amygdala on endocrine function in the rat. Endocrinology *66:* 565—574.

Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 35—46, 1968

EFFECTS OF PARTIAL LESIONS OF THE AMYGDALA IN DOGS. I. APHAGIA *

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(Received June 15, 1967)

There exists a lot of evidence that the amygdaloid complex mediates, among other functions, also the alimentary reactions. Most of the results seem to indicate that the baso-lateral part of the amygdaloid complex exerts an inhibitory effect upon the alimentary reactions. Several authors (Green et al. 1957, Fuller et al. 1957, Wood 1958, Morgane and Kosman 1959, Schwartzbaum 1961) showed that after the amygdalar lesions the animals are hyperphagic and Green et al. (1957) pointed out, that crucial for this hyperphagia is a damage to the area of the baso-lateral division, mainly in the junction between the lateral and basal nuclei. The amygdalar ablation produces, moreover, a disinhibition of positive instrumental alimentary reactions (Brutkowski et al. 1960). Stimulation of the baso-lateral area inhibits instrumental alimentary reactions and food intake (Fonberg and Delgado 1961, Norris 1963).

On the other hand, several authors have shown that the amygdaloid complex mediates also the positive alimentary reactions. Stimulation of the amygdala produces salivation, chewing, swallowing licking, mastication, stomach contractions (Koikegami et al. 1955, Magnus and Lammers 1956, Shealy and Peele 1957, Sano 1958, Sawa 1958, Wood et al. 1958), as well as food intake (Robinson and Mishkin 1962, Grossman and Grossman 1963, Lewińska 1968). After amygdala lesions some authors described aphagia in cats and rats (Anand and Brobeck 1952, Anand et al. 1958,

* This investigation was partially supported by Foreign Research Agreement No. 287707 of U.S. Department of the Health, Education and Welfare under PL 480.

Yamada and Greer 1960, Anand 1961, Kling and Schwartz 1961, Ward 1961, Koikegami 1964, Ursin 1965), and Brutkowski et al. (1962) described a case of longlasting aphagia in a dog after wide surgical ablation of the amygdaloid complex. In that dog the lesion was more extended dorsally than in the others, which were rather hyperphagic, and therefore it seemed reasonable to assume that crucial for the aphagia is a damage to the dorsal part of the amygdaloid complex and/or overlying neighbour structures.

Our experimental results support this assumption. In the previous report (Fonberg 1966) it was shown that lesions aimed into the dorsomedial part of the amygdaloid complex produced aphagia in seven dogs. The present paper reports on further studies on the possible mechanisms of amygdalar aphagia on the basis of the anatomical verification and analysis of the extent of lesions of the individual subjects.

METHODS

Experiments were conducted on ten male, adult, mongrel dogs. Brain lesions were performed under Nembutal anaesthesia by electrocoagulation. In each dog 3 to 4 points were coagulated on either side by DC current, 3—4 mA for one to two minutes. The electrodes were stainless steel needles 0.5 mm in diameter, insulated by an enamel except for 0.5 mm on the tip. They were placed stereotaxically and aimed into the dorsomedial part of the amygdaloid complex, according to the coordinates based on the Atlas of Lim et al. (1960). Animals were under observation for 3—4 months, starting from the first day after operation.

After the experiments were accomplished the animals were anaesthetized and perfused by formaline. Then brain were embedded in the paraffin, and sectioned frontally at 20 μ. Every tenth section was stained by Klüver or Nissl method alternately.

RESULTS

After the operation, the dogs showed a total aphagia, which lasted from 2 to 15 days (Table I). The animals did not show any slightest interest in food, they did not sniff it and during the first 3—5 days after the operation they did not swallow, even when semifluid food was poured far back into the mouth and, therefore, they had to be fed by gastric intubation. In four dogs the forced feeding or intubation was followed by vomiting after a few minutes up to one hour.

Various kinds of food were tested in order to determine the role of the taste preference after lesion. During the period of aphagia the dogs did not eat or lick or even sniff any kind of food. In the first period of recovery, a preference for fresh chopped meat was observed in all dogs

but two, one of which preferred bread with broth, the other milk with eggs and sugar.

The recovery of food intake progressed slowly. First, the dogs started to eat food when it was introduced in small amounts into the mouth. Then, they had to be lured to the bowl by various means (calling with friendly voice, pushing their mouths into the bowl, giving the preferred kind of food, etc.). Step by step, a full recovery occurred and in four dogs the period of aphagia was followed by hyperphagia (A27, A36, A40, A41). In two others (A5 and A33), the periods of hypophagia and hyperphagia interchanged.

Table I

The effects of the destruction of the particular nuclei of the amygdaloid complex

NO. OF DOGS	CENTRAL		MEDIAL		BASAL		LATERAL		CORTICAL		DURATION OF COMPLETE APHAGIA (days)	SUBSEQUENT HYPERPHAGIA
	L	R	L	R	L	R	L	R	L	R		
A 34											16	−
A 5											14	+ −
A 31											11	−
A 28											10	−
A 14											10	−
A 33											9	+ −
A 41											9	+
A 36											6	+
A 40											4	+
A 27											2	+

The order in which the dogs are arranged in the table is based on the duration of aphagia. The dogs in which aphagia lasted longest are placed at the top of the list, those with the shortest aphagia at the bottom. The approximate extent of lesions in all aphagic dogs is shown in three arbitrary gradations: black, more than 70%; stripped, about 50%; dotted, about 30%. L, left hemisphere; R, right hemisphere; +, present; −, absent; + −, interchanged periods of hypophagia and hyperphagia.

Seven aphagic dogs showed the *aggressive-defensive* syndrome which was previously observed in dogs with dorsal amygdalar lesions and described in details elsewhere (Fonberg 1965). In these dogs, the defensive fits appeared from the day after the operation, although in the first post-operative period the dogs spent most of their time lying down half

asleep. Sometimes (once per hour or 3—4 times a day, depending on the individual) however, they got up spontaneously and ran around the cage in a hurry, screaming, whinning or barking. When provoked by noxious stimulation, they developed a full defensive-aggressive syndrome, which increased in time in the „avalanche" form. The defensive symptoms were longlasting and outlasted aphagia by several weeks or months. In three dogs, a gradual increase in aggressiveness was observed during the test period.

It should be mentioned that the development of the aggressive-defensive syndrom cannot be considered as the cause of impairment of the alimentary function, because the alimentary behavior of the dogs was not related to the intensity of the defensive symptoms. In the period of aphagia, the dogs refused to take food even when in a calm and friendly mood, and during the subsequent period of hyperphagia they devoured the food, when presented even just before they showed the aggressive-defensive reactions. When the defensive-aggressive syndrome was not yet fully developped, presentation of food could interrupt the attack. In the state of extreme defensive excitement, the dogs did not pay any slightest attention to food.

Anatomical verification (Fig. 1)

Dog A5: On the left side the whole of the central nucleus and a great part of the medial one were destroyed, whereas the cortical nucleus was injured medially and the basal and lateral nuclei were slightly touched. Besides, there was a lesion in the area of the posterolateral ventral nucleus of the thalamus and partly in the internal capsule and the globus pallidus. On the right side two areas of injury were found. One of them occupied the medial portion of the pyriform cortex and the adjoining part of the hippocampus, part of the medial nucleus and the medial part of the cortical nucleus. The other included putamen and part of claustrum and of entopeduncular nucleus.

Dog A14: The lesion destroyed the lower part of the piriform cortex and damaged the cortical and basal nuclei of the left side. Posterior part of the medial and central nuclei also were damaged on this side. On the right side medial nucleus was completely destroyed as well as a part of the cortical and central nuclei. The optic tract was perforated by the dorsal extent of the lesion. Besides of the amygdaloid complex, the lesion in the left hemisphere involved the internal capsule, cerebral peduncle, and globus pallidus. On the right side medial thalamus and posterior part of hypothalamus were also partly destroyed.

Dog A27: The lesions covered nearly the same areas on both sides. The central nuclei were destroyed completely; in addition, mainly on the left side, the lesion involved the medial nuclei, the caudodorsal portion of the lateral nucleus and the dorsal portion of the basal. Out of the neighbouring structures, the lesion included, on both sides, the posterior parts of the putamen and the lateral portion of the optic tract, and on the right side, the globus pallidus.

Dog A28: The central nuclei were totally destroyed on both sides. Most of the

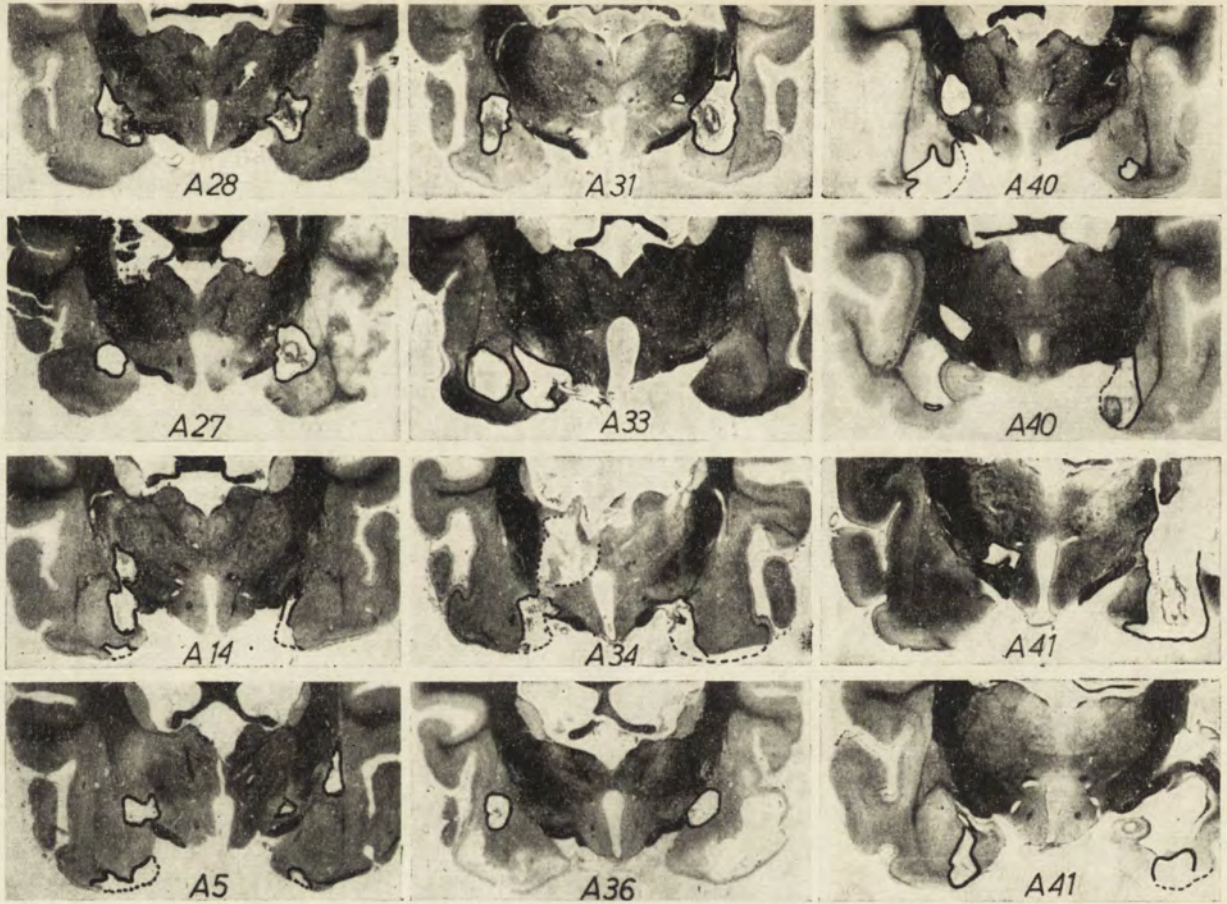

Fig. 1. Typical photographs of frontal sections ot the aphagic dogs, showing site and dimensions of lesions. Because of asymetrical lesions two frontal sections are shown for dogs A40 and A41

medial nuclei were also damaged and in the left hemisphere, the dorsal region of the lateral and basal nucleus and, out of the adjoining structures, the globus pallidus and the medial part of the putamen were destroyed. On the right side, the lesion invaded also a part of the globus pallidus and also the neighbouring portion of the internal capsule, and part of the entopeduncular nucleus.

Dog A31: The lesions in the amygdaloid complex were almost identical on both sides; they involved the central nucleus and partly the medial and basal nuclei and the dorsal portion of the lateral nucleus. In addition, the lesion of the right side included the putamen, partly the entopeduncular nucleus and the adjoining area of the globus pallidus. Anteriorly to the amygdaloid complex, there was a lesion in the substantia innominata. On the left side the putamen and the ventral portion of the claustrum were damaged.

Dog A33: On the left side, the lesion was located in the central and medial nuclei, in a small portion of the cortical nucleus which borders on the medial nucleus and in the posterocaudal portion of the lateral and basal nuclei. In addition to the lesion in the amygdaloid complex, in the same hemisphere there was a lesion in the thalamus, the zona incerta, the lenticular fascicle, as well as part of the entopeduncular nucleus, an edge of globus pallidus and the optic tract. The lesion involved also the ventral part of the putamen. On the right side the area of the amygdaloid complex was not heavily affected by the lesion, which only slightly touched the caudal part of lateral nucleus but, instead, it injured the posterior portion of the medial geniculate body, the posterior part of the thalamus, a part of the substantia nigra, the cerebral peduncle, the optic tract and the hippocampus.

Dog A34: Within the amygdaloid complex, destruction affected the medial nuclei on both sides. On the right side, the cortical nucleus was damaged medially. On the left side, the lesion involved the mediodorsal portion of the amygdaloid complex including the cortical, medial and central nuclei. Besides of the destruction in the amygdaloid complex, large lesions were found in the adjoining structures. On the left side, the lesion involved the cornu Ammonis (in part), the cerebral peduncle, the zona incerta, the optic tract and the entopeduncular nucleus. The thalamus of the left side was deformed by a distension of the lateral ventricles. The lesion destroyed most of the nuclei of the thalamus and hypothalamus up to the medial line. On the right side it touched the hippocampus, and affected the medial portion of the pyriform gyrus adjacent to the horn of Ammon, and a large part of the optic tract.

Dog A36: On both sides, the central nucleus was destroyed by the lesion. Besides, the medial nucleus was partly damaged as well as the dorsal part of the lateral and basal nuclei. Bilaterally, troughout the piriform gyrus there was an atrophy, encroaching upon the ventral part of the basal and lateral nuclei of the amygdaloid complex. The internal capsule, claustrum, putamen and globus pallidus were also partly damaged on both sides.

Dog A40: On the left side, the lesion was localized in two regions, one of them involved the internal capsule and the medial part of the globus pallidus and nucleus entopeduncularis, and the other the ventromedial portion of the amygdaloid complex. Within the amygdaloid complex, destruction involved the cortical and basal nuclei, the caudoventral portion of the lateral nucleus, and partly the medial nucleus. On the right side, the lesion was confined to the amygdaloid complex. The basal nucleus was destroyed completely, whereas the other nuclei were partly damaged. The lesion occupied the ventrocaudal region of the lateral nucleus and the caudal part of the cortical nucleus, its anterior portion being preserved undamaged. The medial nucleus, too, was destroyed in its posterior part and the ventrocaudal region

of the central nucleus was touched. Besides, the lesion involved the horn of Ammon in the lateral ventricle and a portion of the pyriform cortex.

Dog A41: On the right side, the large lesion involved the whole lateral part of the amygdaloid complex. The central and lateral nuclei were destroyed as well as the dorsal part of the basal nucleus. The lateral edge of internal capsule, globus pallidus, putamen and claustrum were also damaged. Within the cortex of the right side the atrophied area involved the ectosylvian, composite and sylvian gyri.

The ventral part of the Ammon's horn was destroyed together with the adjacent piriform cortex in the left hemisphere and the lesion involved also the basal part of the lateral and basal nuclei. On the same side, injury was found in the hypothalamus, laterally to fornix, extending to the nucleus entopeduncularis.

DISCUSSION

The results of this paper indicate that lesions of the dorsomedial part of the amygdaloid complex produce aphagia. This fact may indicate that amygdala participates in the regulation of the alimentary function as a positive center, similar to the „feeding center" found by Anand and Brobeck (1951) and others in the lateral hypothalamus.

As postulated by several authors, the amygdaloid complex is closely connected with the hypothalamus and exerts a regulatory and modulatory influence upon the hypothalamic activity. The amygdalar aphagia was not longlasting, which may be considered to be another proof that amygdala serves as an additional link in the alimentary system, superimposed

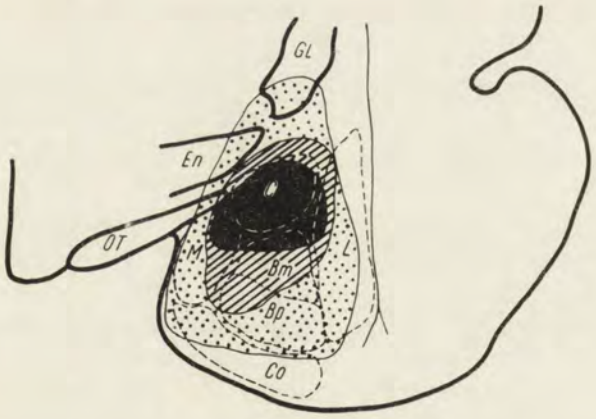

Fig. 2. Schematic superposition of areas destroyed on both sides in all animals with aphagia. Successively darker areas represent 10—25, 25—50 and 50—100% of incidence destruction. C, nucleus centralis of amygdala; M, nucleus medialis; Co, nucleus corticalis; Bm, nucleus basalis magnocelullaris; Bp, nucleus basalis parvocelullaris; L, nucleus lateralis; Gl, globus pallidus; En, nucleus entopeduncularis; OT, optic tract

upon the hypothalamic „centers". In this case the aphagia produced by amygdalar lesions may be compensated by the hypothalamic mechanism.

The problem arises as to which part of the amygdala should be considered as such an additional alimentary center. On the basis of the above anatomical verification, it is not possible to conclude definitely which nuclei are crucial in this respect. In all aphagic dogs central and medial nuclei of amygdala were lesioned at least unilaterally, so it seems reasonable to assume that these nuclei mediate the alimentary reactions. There exists also in the literature some evidence which supports such hypothesis. And so, Shealy and Peele (1957) described the gastrointestinal contractions during the stimulation of the medial nuclei, Wood (1958) reported retching and vomiting and Watanabe (1955) observed salivation during stimulation of the central nucleus. Lewińska (1958) described an increased food intake during stimulation of the medial nucleus.

On the other hand, it is also possible that not only the lesions of the above-mentioned nuclei are responsible for aphagia, but that a similar effect is caused by the interruption of fibers, which cross through the dorsomedial amygdalar region and proceed directly towards hypothalamus.

The central nucleus contains fibres of passage belonging to the preoptic and supracommissura bundles of the stria terminalis (Fox 1943, Miodoński 1965) and reach the lateral preoptic and hypothalamic areas. Furthermore, between the central and medial nuclei, there passes the longitudinal association bundle, which, as shown by Hall (1960, 1963) joints the medial forebrain bundle. This latter, as stressed by Morgane (1961) and others, plays an important role in the alimentary mechanisms.

Besides of the stria terminalis and the longitudinal association bundle, the diffuse ventral system directed to lateral hypothalamus described by Nauta (1961, 1962) may be taken into consideration. Although Hilton and Zbrożyna (1962) showed on cats that this very system carries impulses specific for defensive reactions, it is also probable that some fibers belong to the alimentary system and carry impulses to the feeding center in the lateral hypothalamus.

Some authors suggest that globus pallidus is also involved in the alimentary act. Thus Tarnecki and Konorski (in preparation) observed aphagia and loss of instrumental reactions after lesions situated in globus pallidus, and Morgane (1961) suggested that damage of medial part of globus pallidus or pallidofugal tract carrying fibers to the hypothalamus is crucial for the impairment of the alimentary functions. Some of our aphagic dogs had also the globus pallidus or/and nucleus entopeduncularis damaged and in the case of a dog described by Brutkowski et al. (1962), an amygdala ablation extended also into globus pallidus. Probably these

structures take part in the alimentary system as well as does amygdala. The connections of the particular part of the alimentary system with hypothalamus run through the region above the dorsal amygdala. Therefore we cannot exclude that in some dogs the damage of globus pallidus, nucleus entopeduncularis or their connections with the hypothalamus played a role in the impairment of food intake.

In his recent paper Gold (1967) claims that lesions of the internal capsule are the most efficient in producing aphagia. It is, however, possible that such lesions, as well as the lesions produced by Tarnecki and Konorski (in preparation) and Morgane (1961) destroyed the fibers connecting amygdala with hypothalamus and therefore in all these cases aphagia could have had the same cause as in our experiments.

A lot of fibers passing through the dorsomedial amygdalar area belong to the basolateral system (Ban et al. 1959, Miodoński 1965). It is well known from the experiments of many authors that this system exerts an inhibitory effect on the alimentary functions (Morgane and Kosman 1959, Morgane 1960, Fonberg and Delgado 1961, Fonberg 1963, 1965b, 1967) and that lesions of the basal or lateral nuclei produce hyperphagia (G r e e n et al. 1957, Morgane and Kosman 1957, 1959, Fuller et al. 1957 and others). In some of our dogs also the lateral or basal nuclei were partly damaged (Table I), in the others the fibers originating in the basolateral part could have been cut by the lesion.

In these dogs the decrease of inhibitory influences on the hypothalamic centers, caused by the damage of the basolateral system, may counterbalance the aphagia, produced by the destruction of the dorsomedial part. This assumption would explain the short duration of the impairment of the food intake. Consequently, lesions made in some of our dogs could have a double effect, producing aphagia due to the destruction of dorsomedial part and hyperphagia, caused by the damage of the fibers running from the basolateral part. It is interesting to note that in two of our dogs, after recovery from aphagia, the periods of hypophagia and hyperphagia interchanged and that some other dogs became hyperphagic after several weeks. This latter fact may be explained by assuming, that the impairment of the facilitatory alimentary system of amygdala is easier compensated by the function of hypothalamic centers than is the inhibitory. As an effect, hyperphagia eventually prevailed over aphagia. The results of Wood (1958) and Koikegami et al. (1958) who stressed that lesion situated in the region of medial and central nuclei resulted in hyperphagia in cats, may be also explained by the destruction of the fibers from basolateral system.

SUMMARY

In ten dogs electrolytic lesions of the dorsal part of the amygdaloid complex caused aphagia which lasted for 2—15 days. In all dogs the central and medial nuclei of amygdala were damaged at least unilaterally. It is assumed that these nuclei take part in the alimentary mechanisms in connection with the hypothalamic feeding center. The other possibilities, i. e. the role of the neighbouring structures (globus pallidus, and nucleus entopeduncularis) and also the effect of the damage to the fibers passing through the central and medial nuclei are discussed.

The authors are greatly indebted to Professor J. Konorski, Dr. O. Narkiewicz and Dr. W. Kozak for their valuable remarks. Thanks are also due to Miss B. Kępińska for making histological slides, to Mrs. B. Dziurdzik, Mrs. H. Kurzaj and Mrs. M. Raurowicz for technical assistance and to Mr. A. Rosiak for his devotion in animal care.

REFERENCES

ANAND, B. K. 1961. Nervous regulation of food intake. Physiol. Rev. *41:* 677—708.

ANAND, B. K. and BROBECK, J. R. 1951. Hypothalamic control of food intake in rats and cats. Yale J. Biol. Med. *24:* 123—140.

ANAND, B. K. and BROBECK, J. R. 1952. Food intake and spontaneous activity of rats with lesions in the amygdaloid nuclei. J. Neurophysiol. *15:* 421—430.

ANAND, B. K., DUA, S. and CHHINA, G. S. 1958. Higher nervous control over food intake. Indian J. Med. Research *46:* 277—287.

BAN, T. and OMUKAI, F. 1959. Experimental studies on fiber connections of the amygdaloid nuclei in the rabbit. J. Comp. Neurol. *113:* 245—278.

BRUTKOWSKI, S., FONBERG, E. and MEMPEL, E. 1960. Alimentary type II (instrumental) conditioned reflexes in amygdala dogs. Acta Biol. Exp. (Warsaw) *20:* 263—271.

BRUTKOWSKI, S., FONBERG, E., KREINER, J., MEMPEL, E. and SYCHOWA, B. 1962. Aphagia and adipsia in dog with bilateral complete lesion of the amygdaloid complex. Acta Biol. Exp. (Warsaw) *22:* 43—50.

FONBERG, E. 1963. The inhibitory role of amygdala stimulation. Acta Biol. Exp. (Warsaw) *23:* 171—180.

FONBERG, E. 1965a. Effect of partial destruction of the amygdaloid complex on the emotional-defensive behavior of dogs. Bull. Acad. Pol. Sci., Sér. Sci. Biol. *13:* 429—432.

FONBERG, E. 1965b. The role of the amygdaloid nucleus in animal behavior (in Russian). Brain reflexes (Ibro), Moscow.

FONBERG, E. 1966. Aphagia produced by destruction of the dorsomedial amygdala in dogs. Bull. Acad. Pol. Sci., Sér. Sci. Biol. *14:* 719—722.

FONBERG, E. 1967. The role of the amygdaloid nucleus in animal behavior. Progress Brain Res. *22:* 273—281.

FONBERG, E. and DELGADO, J. M. R. 1961. Avoidance and alimentary reactions during amygdala stimulation. J. Neurophysiol. *24:* 651—664.

FOX, C. A. 1943. The stria terminalis, longitudinal association bundle and praecommissural fornix fibers in the cat. J. Comp. Neurol. *79:* 277.

FULLER, J. L., ROSVOLD, H. E. and PRIBRAM, K. H. 1957. The effect on affective and cognitive behavior in the dog of lesions of the piriform — amygdala — hippocampal complex. J. Comp. Physiol. Psychol. *50:* 89—96.

GOLD, R. M. 1967. Aphagia and adipsia following unilateral and bilaterally asymetrical lesions in rats. Physiol. Behavior *2:* 211—220.

GREEN, J. D., CLEMENTE, C. E. and de GROOT, J. 1957. Rhinencephalic lesions and behavior in cats. J. Comp. Neurol. *108:* 505—546.

GROSSMAN, S. P. and GROSSMAN, L. 1963. Food and water intake following lesions or electrical stimulation of the amygdala. Amer. J. Physiol. *205:* 761—765.

HALL, E. A. 1960. Efferent pathways of the lateral and basal nuclei of the amygdala in cats. Anat. Rec. *136:* 205.

HALL, E. A. 1963. Efferent connections of the basal and lateral nuclei of the amygdala in the cat. Amer. J. Anat. *113:* 139—151.

HILTON, S. M. and ZBROŻYNA, A. W. 1962. Amygdaloid region for defense reactions and its afferent pathways to the brain stem. J. Physiol. *165:* 160—173.

KLING, A. and SCHWARTZ, N. B. 1961. Effect of amygdalectomy on feeding in infant and adult animals. Fed. Proc. *20:* 335.

KOIKEGAMI, H. 1964. Amygdala and other related limbic structures. II. Functional experiments. Acta Med. Biol. *12:* 73—266.

KOIKEGAMI, H., FUSE, S., YOKOYAMA, T., WATANABE, T. and WATANABE, H. 1955. Contribution to the comparative anatomy of the amygdaloid nuclei of mammals with some experiments on their destrution or stimulation. Fol. Psychiat. Neurol. Jap. *8:* 326—370.

KOIKEGAMI, H. S., FUSE, S., HIROKI, S., KAZAMI, T. and KAGAYAMA, Y. 1958. On the inhibitory effect upon the growth of infant animals or on the obesity in adult cat induced by bilateral destruction of the amygdaloid nuclear region. Fol. Psychiat. Neurol. Jap. *12:* 207—223.

LEWIŃSKA, M. K. 1968. Inhibition and facilitation of alimentary behavior elicited by stimulation of amygdala in cats. Acta Biol. Exp. (Warsaw) *28:* (in press).

LIM, R. K. S., LIU, CH. and MOFFITT, R. L. 1960. A stereotaxic Atlas of the dog's brain. Charles C. Thomas publ. Springfield Ill.

MAGNUS, O. H. and LAMMERS, H. J. 1956. The amygdaloid — nuclear complex. Fol. Psychiat. Neurol. Neurochir. Neerl. *59:* 555—582.

MIODOŃSKI, R. 1965. Myeloarchitectomies of the amygdaloid complex of the dog. Acta Biol. Exp. (Warsaw) *25:* 263—287.

MORGANE, P. J. 1961. Alterations in feeding and drinking behavior of rats with lesions in globi pallidi. Amer. J. Physiol. *201:* 420—428.

MORGANE, P. J. 1961. Medial forebrain bundle and „feeding centers" of the hypothalamus. J. Comp. Neurol. *117:* 1—26.

MORGANE, P. J. and KOSMAN, A. J. 1957. Alterations in feline behavior following bilateral amygdalectomy. Nature *180:* 598—600.

MORGANE, P. J. and KOSMAN, A. J. 1959. A rhinencephalic feeding center in the cat. Amer. J. Physiol. *197:* 158—162.

NAUTA, W. J. H. 1961. Fibre degeneration following lesions of the amygdaloid complex in the monkey. J. Anat. *95:* 515—531.

NAUTA, W. J. H. 1962. Neural associations of the amygdaloid complex in the monkey. Brain *85:* 505—520.

NORRIS, F. H. 1963. Arrest of activity by temporal lobe stimulation. Neurology *13:* 895—898.

ROBINSON, B. W. and MISHKIN, M. 1962. Alimentary responses evoked from forebrain structures in Macaca mulatta. Science *136:* 3512, 260—262.

SANO, T. 1958. Motor and other responses elicited by electrical stimulation of the cat's temporal lobe. Fol. Psychiat. Neurol. Jap. *12:* 152—176.

SAWA, M. 1958. Functional properties of the amygdala (Japanese, English summary). Psychiat. Neurol. Jap. *60:* 1021—1026.

SCHWARTZBAUM, J. S. 1961. Some characteristies of „amygdaloid hyperphagia" in monkeys. Amer. J. Psychol. *74:* 252—259.

SHEALY, C. N. and PEELE, T. L. 1957. Studies on amygdaloid nucleus of cat. J. Neurophysiol. *20:* 121—139.

URSIN, H. 1965. Effect of amygdaloid lesions on avoidance behavior and visual discrimination in cats. Exp. Neurol. *11:* 298—317.

WATANABE, T. 1955. Experimental researches on the amygdaloid nuclei and paria-mygdaloid cortex with special references to salivation. Niigata Med. J. *69:* 777—787, 857—868, 958—967.

WARD, H. P. 1961. Tegmental selfstimulation after amygdaloid ablation. Arch. Neurol. *4:* 657—659.

WOOD, C. D. 1958. Behavioral changes following discrete lesions of temporal lobe structures. Neurology *8:* 215—220.

WOOD, C. D., SCHOTTELIUS, B., FROST, L.L. and BALDWIN, M. 1958. Localization within the amygdaloid complex of anesthetized animals. Neurology *8:* 477—480.

YAMADA, T. and GREER, M. A. 1960. The effect of bilateral ablation of amygdala on endocrine function in rat. Endocrinology *66:* 565—574.

Collegium Internationale Activitatis Nervosae Superioris
(Section of the World Psychiatric Association)

FIRST INTERNATIONAL CONGRESS ON HIGHER NERVOUS ACTIVITY

Milan, Italy, 18th to 20th October, 1968

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Milano, Italy

SECOND INTERNATIONAL SYMPOSIUM ON RADIOSENSITIZING AND RADIOPROTECTIVE DRUGS

ROMA

Istituto Superiore di Sanità

FIRST ANNOUNCEMENT

The Second International Symposium on Radiosensitizing and Radioprotective Drugs will be held in Rome at the Istituto Superiore di Sanità from 6th to 8th May 1969.

Like the first one, the present Symposium will be under the auspices of the European Society for Biochemical Pharmacology.

The Symposium is planned to provide an opportunity for the exchange of information on recent advances in the field of radiation protection and sensitization.

Everybody who is interested in receiving further information may contact either one of the scientific secretaries of the Symposium at the following addresses

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Sloan-Kettering Institute for Cancer Research
Donald S. Walker Laboratory
145 Boston Post Road
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Dr. M. Quintiliani
Istituto Superiore di Sanità
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Roma 00161
Italy

Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 47—56, 1968

THE HYPOTHALAMIC LESIONS: EFFECTS ON APPETITIVE AND AVERSIVE BEHAVIOR IN RATS

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(Received May 15, 1967)

Changes in both the general and the alimentary behavior of rats following lesions of the so called hypothalamic feeding center were extensively studied by a number of authors (Olds 1958, Teitelbaum and Epstein 1962, 1963, Rodgers et al. 1965 and others). It was also shown that the postoperative aphagia is transformed into a preferential hypophagia and this, in turn, in some animals into a preferential hyperphagia with its characteristic symptoms of voracity and obesity (Morrison and Mayer 1957, Graff and Stellar 1962, Teitelbaum 1964). These symptoms are explained by the increased sensitivity of operated animals to the taste of food.

In all these studies the effects of hypothalamic lesions upon CRs were rarely taken into consideration. According to Chereshniev (1960) lesions of the posterolateral portion of the hypothalamus in dogs causes a persistent abolition of the alimentary CRs and makes the elaboration of such reaction difficult. In experiments involving lesions of the lateral hypothalamus in rabbits we showed that, in addition to the symptoms described above, there also occur drastic disorders in the avoidance CRs (Balińska and Wyrwicka 1961, Balińska et al. 1964). These disorders occur simultaneously with the abolition of the alimentary CR (Balińska 1963, 1965, 1966, Balińska et al. 1966). These findings induced us to carry out a similar analysis of alimentary and defensive CRs in rats.

MATERIAL AND METHODS

Subjects. Experiments were performed on 66 adult male hooded rats of Druckray strain, approximately 3 months old and weighing, at the beginning of the experiment, between 200 and 230 g. In each cage, there were five to six rats. They were fed the Larsen standard diet and given fresh water every day. After two weeks of the observation period, bilateral hypothalamic lesions were made.

Surgery. Lateral hypothalamic lesions were made stereotaxically (P 2, L 2, V 8 according to Fifkowă and Maršala 1960) by passing a direct anodal current of 1.5 mA for 20 sec under a light ether anaesthesia. The observation of animals' behavior started within 15 min after the lesion was produced.

Experimental procedure with the alimentary conditioned reactions. An experimental cage, 30×15×15 cm in size, with a round hole in its bottom was used. A small bowl was placed beneath the hole and the rats had to reach food from the bowl using their forepaws. An acoustic stimulus was emitted every minute for five sec. If within the following 10 sec the rat did not approach the feeding place, no food was presented in a given trial. A 0.5 g pellet of a wet food of the Larsen type was used as a single reinforcement. Thirty trials were performed each day. The performance of 28 correct responses in 30 trials during five experimental sessions was adopted as a criterion.

Experimental procedure with the defensive conditioned reactions. An experimental cage, 80×15×150 cm in size, was used to produce the avoidance reaction. Electrical shocks were given to the paws of the animals through the electrified floor. A 15×18 cm electrically insulated platform was mounted at the end of the cage opposite to the starting place. The task of the animal was to run to the platform within five sec after it was put on the starting line. A correct performance of 28 responses in 30 successive trials during five experimental sessions was adopted as a criterion.

Control animals. Naive animals with intact brain were used for control tests. In both the alimentary and defensive experimental situation, the procedure applied was identical with that used in the experimental groups.

In all animals both the alimentary and defensive CRs were elaborated.

Anatomical verification of the lesions. At the end of the experiments, the animals were anaesthetized with ether and their brains were perfused with 4% formalin. Frozen sections were cut to 50 slices and stained using the Nissl technique and, thereafter, the lesions were microscopically verified. The animals were grouped depending on the placement of lesions in their brain.

RESULTS

General behavior of the operated animals

An hour after the operation, a clear-cut increase in the motility was observed in all rats. The animals continually scratched the walls of the cages. Six to eight hours later, they became immobile and remained so for a few days. During the first three to nine days they refused food and water. In order to keep them alive, they received dailly subcutaneous injections of 10 ml of 4% glucose solution (Balińska 1963). The period of complete

aphagia and immobility was followed by a phase of alimentary preference. The rats refused dry pellets of food and did not drink water but they ate drops of palatable liquid diet injected directly into their mouths. This diet consisted of 100 g of powdered milk, 100 g of sugar, 1 egg and 500 ml of water mixed in a shaker. Such a mixture was given to the aphagic rats 4—6 times a day. After a few days of such assisted food intake, the animals began to eat spontaneously. Occasional licking of the liquid diet changed soon into hyperphagia and they distinctly put on flesh. After several days of feeding on this palatable liquid food, the rats began to eat solid tasty food (wet cakes) but they continued to refuse dry pallets and water. Soon they became fat and displayed characteristics symptoms of hyperphagic animals. This alimentary preference persisted for 1 to 22 days and, then, the operated rats gradually returned to their normal diet. The experiments started as soon as the alimentary behavior of the rats became identical with that of the control animals.

Some of the operated animals displayed distinct changes in their affective behavior as manifested by an increase of the defensive responses. Accordingly the animals were divided into two groups. The first group consisted of 44 rats with unchanged emotionality, and the second — of 22 animals with increased emotional responses. The latter animals, unlike the remaining rats, displayed a strong orientation reaction, an increase in responsiveness to external stimuli, and symptoms of fear combined with aggression. Since the CRs were different in both these groups, they will be described separately.

Animals with an unchanged emotionality

The neuroanatomical verification of the brains indicated two types of the localization of lesions. In 24 rats (subgroup A), lesions were placed in the lateral portion of the hypothalamus, containing small accumulations of nerve cells (P + 2, L 2, V 8, Fig. 1). In the remaining 20 animals (subgroup B) lesions were more extensive, situated higher, and, in addition to the posterolateral parts of the hypothalamus, they also included the lower margin of the zona incerta (Fig. 2).

The period of aphagia and adipsia lasted — in the animals of subgroup A — on the average, for 2.8 $\pm$ 0.7 days. The phase of the preferential hypophagia was also not very long lasting (5.5 $\pm$ 1.0 days). A quick transition was observed from the stage of the sweet liquid food intake to that of the sweet solid diet. In the case of the animals of subgroup B, the period of aphagia and adipsia was somewhat longer (4.6 $\pm$ 1.5 days) and the phase of the preferential hypophagia was quite long (12.9 $\pm$ 2.3 days). The persistent intake of sweet liquid food had the properties of hyperphagia and

was accompanied by a considerable increase of the animals' weight. The transition to the normal diet took place with the omission of the stage of the intake of sweet solid food.

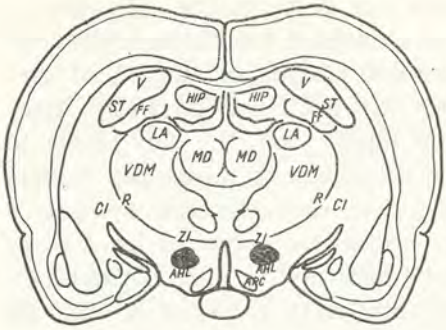

Fig. 1. Reconstruction of lesions of the lateral hypothalamus in rats which remained emotionally unchanged, subgroup A. AHL, area hypoth. later; ARC, n. arcuatus; CI, capsula interna; F, fornix; FF, fimbria of fornix; LA, n. lateralis anterior; MD, n. medialis dorsalis thalami; OT, optic tract; PC, pedunculi cerebri; R, n. reticularis; STH, n. subthalamicus; V, ventriculus; Zi, zona incerta

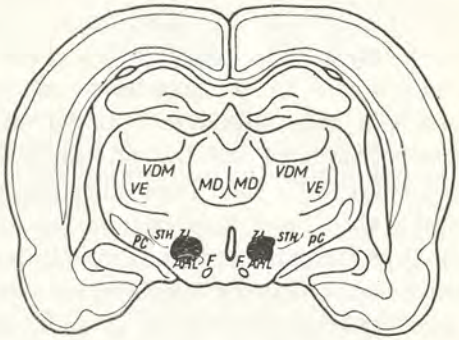

Fig. 2. Reconstruction of lateral hypothalamic lesions in rats which remained emotionally unchanged, subgroup B. Denotations as in Fig. 1

The alimentary CR. Subgroup A. During the first few days the animals displayed a complete lack of interest in food in the experimental situation. During the entire experimental period, they crouched immobile and did not respond to any stimuli. This situation remained unchanged even when they starved. After a few days infrequent attempts were observed of taking the food out of the bowl but it was only after 200 trials that the number of responses increased (Fig. 3).

Subgroup B. During the entire experimental period, the rats did not show any interest in food. During 600 trials, they crouched immobile with their backs turned towards the food-tray. Starving caused the recovery of the preferential hyperphagia phase but it did not exert any influence on the course of experiments. Eventually, no alimentary CR was produced in the rats of this subgroup (Fig. 3).

The defensive CR. Subgroup A. In the control group of rats, the escape response was evoked nearly immediately (after 2 trials), whereas in the lateral hypothalamic rats it was somewhat delayed. Likewise, the avoi-

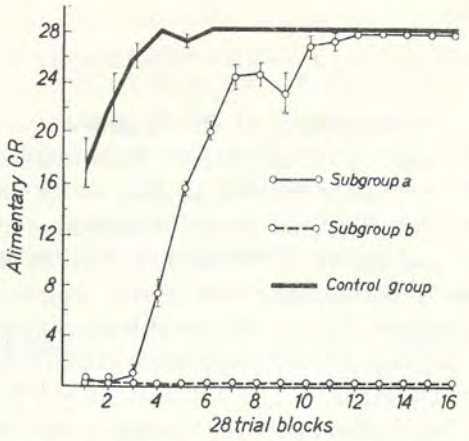

Fig. 3. Formation of the alimentary CR in rats with unchanged emotionality (average values)

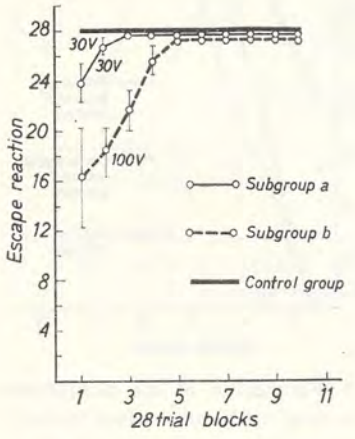

Fig. 4. Escape reaction in rats with an unchanged emotionality (average values)

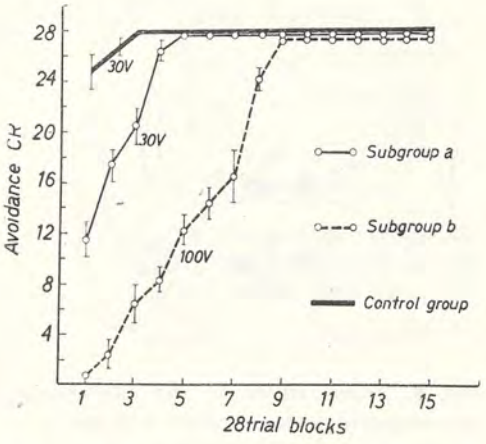

Fig. 5. Formation of the avoidance CR in rats with unchanged emotionality (average values)

dance CR was also established much later than in the control group and it reached a 100% performance only after about 90 trials (Fig. 4 and 5).

Subgroup B. In the animals with additional lesions, located in the zona incerta, the defensive responses were much poorer. The escape response could not be elicited by a 30 V electrical shock and, to elicit it, the intensity of the shock had to be increased to 100 V. Only then, after a few experimental days, the escape response occured in all trials (Fig. 4 and 5).

The avoidance CR was established with even greater difficulty. After nine sessions, however, the animals started to perform it in 100% of trials.

Animals with increased defensive reactions

The histological investigations of the brains have shown that lesions were asymmetrical and, apart of lateral hypothalamus, they included other structures of the hypothalamus, as well as its vicinities. All lesions were located in the posterior part of the hypothalamus and included the lateral mammillary nucleus (P + 2.5, L 2, V 8.5). In 9 aut of 22 rats the posterior part of the hypothalamus and lateral mammillary nucleus were only unilaterally damaged (Fig. 6). Bilateral lesions caused a longer lasting aphagia (6.0 ± 1.3 days) and food preference (18.0 ± 2.4 days) than those evoked by unilateral lesions (3.1 ± 1.0 and 11.5 ± 2.1 days resp.). The intake of the sweet liquid food occured during a few hours only.

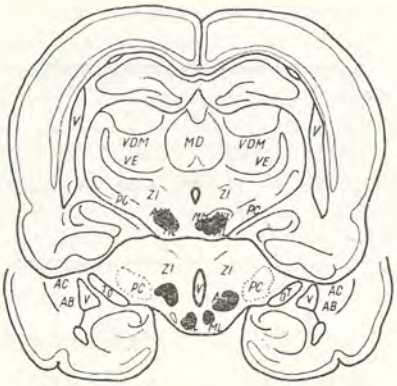

Fig. 6. Reconstrution of the lateral hypothalamic lesions in rats with intensified emotional reactions. Top, symmetric bilateral lesions of area hypoth. later., and n. mammillaris lateralis. Bottom, unilateral lesions of area hypoth. later. and n. mammillaris lateralis. Denotations as in Fig. 1

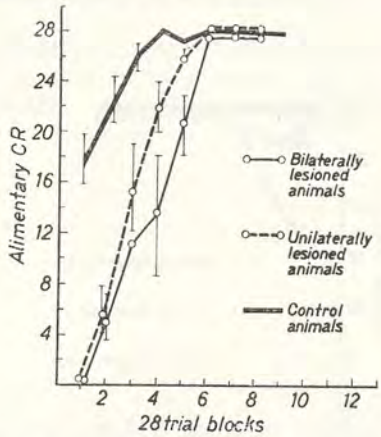

Fig. 7. Formation of the alimentary CR in rats with intensified emotional responses (average values)

The alimentary CR. A very strong aggression, occuring in the rats, hindered the establishment of the alimentary CR. The lack of correct responses, observed in the first day of experiments, as well as a great number of incorrect responses that occured on subsequent days, were caused not so much by the lack of interest in food as by the intensification of emotional reactions (Fig. 7).

The defensive CR. The excessive sensitivity to the electrical shock, displayed by rats with increased defensive reactions, compelled us to lower the voltage of the shock from 30 to 8 V. Both the bi- and unilateral lesion of the ventral portion of the posterolateral hypothalamus evoked strong symptoms of fear, combined with aggression, which made it difficult to reach the criterion in the avoidance CR and impaired the escape reaction (Fig. 8 and 9). The experimental situation alone evoked a strong fear reaction throughout the experimental period.

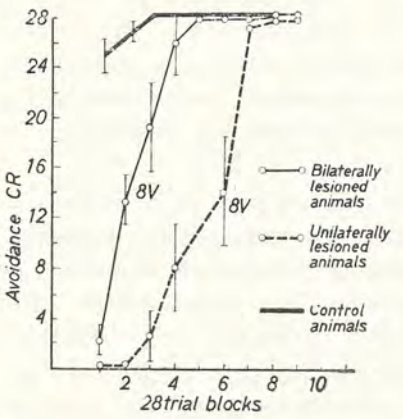

Fig. 8. Formation of the avoidance CR in rats with intensified emotional responses (average values)

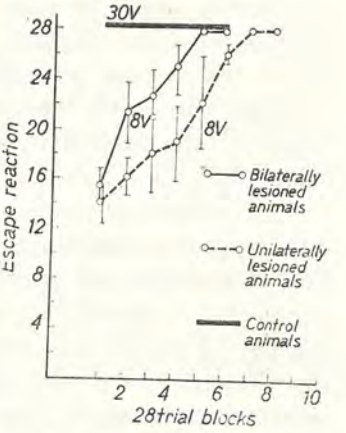

Fig. 9. Escape reaction in rats with intensified emotional reaction (average values)

DISCUSSION

Our results show that lesions placed laterally to the fornix greatly impaired the formation of instrumental CRs, both alimentary and defensive. Small lesions, including the cellular parts of the lateral hypothalamus, produced only temporary inability to establish the alimentary and defensive CRs. More extensive lesions which also included the ventral part of the zona incerta produced a more severe effect: the alimentary CRs could not be established at all, whereas the defensive CRs were established only when the intensity of the shock was considerably increased. On the other hand, lesions placed in the posterior part of the lateral hypothalamus, including the lateral mammillary nucleus, produced a great increase of the defensive behavior of the fear-aggression character. In these animals it was possible to elaborate both the alimentary and avoidance CRs.

The morphological analysis of lesions was hindered to a considerable extent by an unusually complex structure of what is called an alimentary center. Slightly myelinated and unmyelinated fibers of the fasciculus medialis telencephali pass between the group of cells, termed as the bed nuclei of the diencephalic periventricular system. The branchings of this system form connections between structures defined as the vegetative centers of the brain (Crosby et al. 1962). Physiological studies have showed motivational and vegetative significance of this system of fibers (Olds and Hogberg 1964, Coons et al. 1965, Harvey and Lints 1965, Mendelson and Chorover 1965, Rich et al. 1965, Rodgers et al. 1965, Valenstein and Campbell 1966). Another system consists of myelinated fibers, which pass through the hypothalamus and run to the globus pallidus (Crosby et al. 1962) and are of a motor character. Consequently, the lesion of the lateral hypothalamus produces a complex aseemblage of alimentary, emotional and motor symptoms.

Our experiments show that lesions in the ventral part of the posterolateral hypothalamus, including n. mammillaris lateralis cause a prolongation of aphagia and preference for a palatable liquid diet. However, no decrease in alimentary motivation was produced in these animals after the period of aphagia had passed off. Initial difficulties in establishing the alimentary CR were caused by the intensification of emotional reactions which resulted from defensive experiments carried out simultaneously. As shown by Graff's and Stellar's (1962) investigations, the posterolateral hypothalamus, area premammillaria and mammillary complex are of a decisive importance to the food preference and finickiness.

Lesions placed in the dorsal part of the lateral hypothalamus including part of the zona incerta, caused a temporary or total impairment of alimentary motivation in the experimental situation. Likewise in the defensive situation, these animals displayed a decreased sensitivity to the electric shock, and decrease in fear. Regardless of whether these changes were caused by the lesion of cells or fibre bundles, we may assume that in the lateral hypothalamus there are centers for both alimentary and defensive motivation, situated near each other and at probably partly overlapping.

SUMMARY

Disorders in motivation and in formation of the alimentary and defensive CRs are observed after lesions in the lateral hypothalamus in rats. Lesions affecting predominantly the fibres cause strong and long-lasting disorders in the alimentary and defensive motivation. Lesions affecting

predominantly cells produce such effect only temporarily. Lesions including the posterior part of the hypothalamus and part of the mammillary complex cause very strong aggression which sometimes prevent the rats from performing their tasks.

REFERENCES

BALIŃSKA, H. 1963. Food intake and type II conditioning in lateral hypothalamic rabbits survived under forced hydration. Acta Biol. Exp. (Warsaw) *23:* 115—124.

BALIŃSKA, H. 1965. The effect of intravenous injection of glucose on food intake and conditioned reflex activity in rabbits with lesions of the hypothalamic feeding centers. Acta Biol. Exp. (Warsaw) *25:* 121—131.

BALIŃSKA, H. 1966. Differentiation learning in rabbits with lesions of the frontal cortex or the hypothalamus. Acta Biol. Exp. (Warsaw) *26:* 259—266.

BALIŃSKA, H. and WYRWICKA, W. 1961. Effect of lesions in the lateral hypothalamus on the defensive conditioned reflexes type II (avoidance) in rabbits. Bull. Acad. Pol. Sci., Sér. Sci. Biol. *9:* 223—226.

BALIŃSKA, H., BRUTKOWSKI, S. and STEFANICKA, J. 1966. Fronto-hypothalamic control over food-reinforced conditioned reflex performance and differential inhibition in rabbits. Acta Biol. Exp. (Warsaw) *26:* 3—23.

BALIŃSKA, H., ROMANIUK, A. and WYRWICKA, W. 1964. Impairment of conditioned defensive reactions following lesions of the lateral hypothalamus in rabbits. Acta Biol. Exp. (Warsaw) *24:* 89—97.

COONS, E. E., LEVAK, M. and MILLER, N. E. 1965. Lateral hypothalamus: learning of food-seeking response motivated by electrical stimulation. Science *150:* 1320—1321.

CHERESHNIEV, I. A. 1960. The effects of hypothalamic stimulation and lesions on conditioned reflex activity in dogs (in Russian). Zh. Vyssh. Nerv. Deyat. *10:* 896—902.

CROSBY, E. C., HUMPHREY, T. and LAUER, E. W. 1962. Correlative anatomy of the nervous system. The Macmillan C., New York.

FIFKOVÁ, E. and MARŠALA, J. 1960. Stereotaxic atlas for the cat, rabbit and rat. Publishing House Cech. Acad. Sci., Prague.

GRAFF, H. and STELLAR, E. 1962. Hyperphagia, obesity and finickiness. J. Comp. Physiol. Psychol. *55:* 418—424.

HARVEY, J. A. and LINTS, C. E. 1965. Lesions in the medial forebrain bundle delayed effects on sensitivity to electric shock. Science *148:* 250—252.

MENDELSON, J. and CHOROVER, S. C. 1965. Lateral hypothalamic stimulation in satiated rats: T maze learning for food. Science *149:* 559—561.

MORRISON, S. D. and MAYER, R. J. 1957. Adipsia and aphagia in rats after subthalamic lesions. Amer. J. Physiol. *191:* 248—254.

OLDS, J. 1958. Satiation effects in self-stimulation of the brain. J. Comp. Physiol. Psychol. *51:* 675—678.

OLDS, J. and HOGBERG, D. 1964. Subcortical lesions and maze retention in the rat. Exp. Neurol. *10:* 296—304.

RICH, I. and THOMPSON, R. 1965. Role of the hippocampo-septal system, thalamus and hypothalamus in avoidance conditioning. J. Comp. Physiol. Psychol. *59:* 66—72.

RODGERS, W. L., EPSTEIN, A. N. and TEITELBAUM, P. 1965. Lateral hypothalamic aphagia: failure or motivational deficit. Amer. J. Physiol. *208:* 334—342.

TEITELBAUM, P. 1964. Appetite. Proc. Amer. Philosoph. Soc. *108:* 464—472.

TEITELBAUM, P. and EPSTEIN, A. N. 1962. The lateral hypothalamic syndrome: recovery of feeding and drinking after hypothalamic lesions. Psychol. Rev. *69:* 74—90.

TEITELBAUM, P. and EPSTEIN, A. N. 1963. The role of taste and smell in the regulation of food and water intake. In: Zotterman, Y. (ed.), Olfaction and taste. Pergamon Press, Oxford, p. 347—366.

VALENSTEIN, E. S. and CAMPBELL, J. E. 1966. Medial forebrain bundle-lateral hypothalamic area and reinforcing brain stimulation. Amer. J. Physiol. *210:* 270—274.

Acta Biol. Exp. (Warsaw), vol. 28, no. 1, p. 57—58, 1968

Book reviews

An introduction to the behaviour of ants by J. H. SUDD. Edward Arnold (Publishers) Ltd., London, 1967, VIII + 200 p., illust.

In the recent years, the myrmecological literature in English language lacked a comprehensive treatise embracing the broad scope of the ant behavior. This gap has neither been entirely filled up by the American edition of the well-known book of W. Goetsch nor — even less so — by a mere reprint of the classical work of W. M. Wheeler. Thus the new and modern book written by an English myrmecologist-ethologist, Dr. John H. Sudd deserves a full appreciation.

The avowed aim of the book which is the result of the author's search among some of the many publications (recently estimated at about 35.000 items) has been to facilitate the search for other authors. No doubt that this aim has been successfully achieved.

The book constitutes a detailed introduction to the ant ethology and, as such, it may be compared to similar comprehensive works on behavior of selected groups of animals as, for instance, the „Behaviour and social life of honey bees" by Colin G. Ribbands. It is extensively based on some 470 bibliographic items embracing the main classical works from the beginning of the past century, and especially the recent papers published since 1925. (It is obvious that the references may serve only as an introduction to the whole score of them). In blending his own experience with the collected information from those sources, the author has written an extensive and sufficiently documented survey.

The book has nine sections, the first of which, the introduction, presents a brief general account of classification of ants and of their societies. It is followed by another section on the roots of behavior. This gives some idea of anatomy of the central nervous system of the ant although the author has resigned to explain its role in producing the ant's behavior; much more attention is paid to effectors and sense organs; finally, one finds chapters on the rhythm of activity and on the communication between ants.

The series of special sections on the behavior of ants begins with that devoted to the problem of navigation including the orientation by scent trails. The fourth section concerns the nests of ants — their types, nest-site selection, and ways of building them. The following two sections concern the problem of food. The answer to the question „How ants get their food" is a subject matter of the fifth section, and this part also makes up a reference to the problems discussed before, viz. navigation by scent trails and the so-called language. The subsequent section deals with the food-traffic among the nest mates. One also finds here the information about ants' guests, parasitic ants — as about slave raids, ants' cattle and food stores in the former section.

A problem of care of the offspring, discussed in the sixth section, leads us to the next one devoted to colony reproduction. A chapter about the temporary social parasitism supplements the information on the interspecific relationships contained in the previous two sections. The last of these special sections, the eighth one, concerns the organization of ant colony, i. e., such problems like polyethism, specialization, and co-operation in the group work. There is also a chapter devoted to the learning abilities of ants.

The book ends with a short section where the author gives theoretical considerations about the evolution of social behavior in ants, as well as accounts of systematics and geography of ant behavior, and of the social history of ants. The last chapter contains the discussion of the view that an ant colony constitutes a „superorganism".

The work is written in an almost telegraphic style and, therefore, cannot be recommended to the general reader. It presents, however, a valuable guide to problems and literature for the post-graduates who intend to specialize in ant ethology. It will also be appreciated by many young ethologists, non-myrmecologists interested in certain wider aspects of behavior, as animal navigation or communication. Considering such a circle of readers, it seems to be inadequate to use the shorthand term „language". It is to be complained that the word „communication" has not been exclusively used by the author instead.

Dr. John H. Sudd decorated his book with two plates consisting of four black-and-white photographs. The 49 line drawings and diagrams complete the work. There is a subject and species index which will be helpful to the reader who wants to use the publication as a reference-book.

Jerzy A. Chmurzyński, Warsaw, Poland

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PAŃSTWOWE WYDAWNICTWO NAUKOWE
WARSZAWA 1968

Printed in Poland

Wojskowa Drukarnia
w Łodzi

Cena zł 15.—

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