GASEOUS EXCHANGE AND GASTRIC SECRETION IN DOGS AS RELATED TO VARIOUS FUNCTIONAL STATES OF THE CEREBRAL CORTEX

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I.P. Pavlov's pupils [1, 2, 3, 4] have demonstrated the functional relationship between the cerebral cortex and the internal organs.

However, much remains unknown today concerning the problem of the cortical control of gaseous exchange and of gastric secretion.

The object of the present investigation is to explain the relationship between changes in gastric secretion and in oxidation processes as affected by various experimental conditions; measurements have been made before and during the elaboration of conditioned reflexes, after establishing a stereotype, and after "confusing" nervous activity.

METHOD

Three sets of experiments were carried out on 2 dogs with an isolated stomach pouch (Rex, a mongrel of 3 years weighing 18 kg, and Turus, a mongrel of 4 years, weighing 19 kg). During the first stage of the experiment, both dogs were given the same food, which consisted of soup and meal (usually oatmeal), meat, vegetables, black bread, and bones. In all, 120 experiments were performed.

Before the experiments, the dogs were made familiar with the conditions and with the set-up of the experiment.

During this period,their daily program was arranged in the same way as it was subsequently during the experiments: at 8 A.M., after a walk, and after staying for 1 hour on the stand in the conditioned reflex chamber, the animals were transferred to another room, and after 20 minutes, when the pulse was normal, the gaseous exchange was determined using a Douglas-Haldane bag*.

After the gaseous exchange had been measured, observations were made on gastric secretion, and as soon as the reaction had become neutral, a food stimulus consisting of meat, bread, or milk was given, after which, observations on gastric secretion were made for 5 hours. Portions of the juice were measured at 15 minute intervals, and the hourly amounts were titrated for acid with N/50 NaOH.

After this, the main experiment was carried out, and here the change in conditions was that when in the conditioned reflex chamber, the dogs did not merely remain standing, but for a period of 1 hour defensive conditioned reflexes were elaborated. For each dog, the positive conditioned stimuli were horn No. 6 and siren No. 8. The differentiated stimulus was a metronome working at 50 strokes per minute. This differentiation was considered in connection with the difficulty of elaborating a finer one.

*The accuracy of the indications obtained by this method was checked in M.N. Shaternikov's laboratory by his assistants O.P. Molchanova and N.G. Shchepkin.

The unconditioned stimulus used was the voltage from an induction coil. The stimulating electrodes were connected to the right hind foot. A reinforcement was given after each conditioned stimulus.

The conditioned stimuli were used in a strictly determined sequence and were applied for a constant length of time, the conditioned stimulus being given for 8 seconds, and the unconditioned for 2 seconds. The animal's defensive reaction, which consisted of withdrawing the foot, was recorded on a kymograph, using a pneumatic transmitter. The strength of the conditioned reaction was recorded by crosses, a weak reaction being represented by one, a moderate by two, and a strong reaction by three.

After working in the conditioned reflex chamber, as in the control experiments, the dogs were transferred into another room, where the gaseous exchange was determined and gastric secretion measured.

RESULTS

After having established the basic rates of gaseous exchange and gastric secretion, the oxygen absorbed per kilogram weight of the animal was found to vary from 0.30 to 0.36, having an average value of 0.33 liters. The carbon dioxide liberated varied from 0.22 to 0.28, with a mean value of 0.25 liters, the respiratory quotient was 0.77, and the pulmonary ventilation had a value of 11 liters.

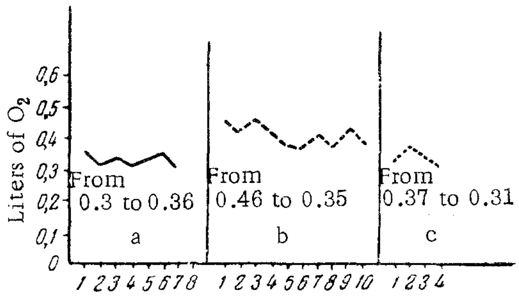

Fig. 1. Oxygen consumption per kilogram per hour in the dog Rex. a) In control experiment; b) during elaboration of conditioned reflexes; c) with "confusion".

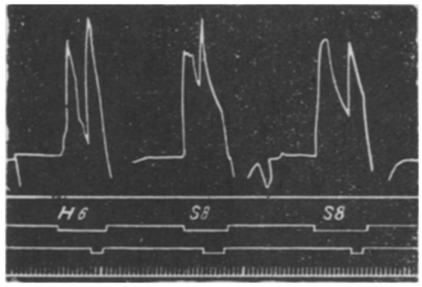

Fig. 2. Defensive motor reaction on reinforcing conditioned reflexes. Curves, from above downwards: motor reaction, marker of conditioned stimulus marker, time marker in seconds. Response on left) conditioned reaction; responses on right) unconditioned reaction.

Fig. 1 shows the oxygen requirement during the acclimatization period (A), and during the elaboration of conditioned reflexes (B). During the first stage of the development of a conditioned reflex, the animal absorbed 0.46 liters of O_2 per hour per kg weight, and when the reflexes had become established, the amount absorbed was 0.35 liters, i.e., the oxidative processes returned approximately to the initial value (Fig. 1, b).

For the sake of clarity, we have given the results of two experiments, Nos. 29 and 30 (Tables 1 and 2 and Fig. 2), and it can be seen that the dog's reaction to both the conditioned and the unconditioned stimulus are of the same strength (two or three crosses), while the animal remains completely unresponsive to the differentiated stimulus of the bell.

After establishing this absolute differentiation, and forming a stereotype from the system of positive and inhibitory stimuli (see Tables 1 and 2), the nervous activity was then "confused" by presenting simultaneously positive and inhibitory stimuli consisting of siren 8 + metronome at 50 strokes per minute. As the result of this treatment, the dog retained only a weak orienting reaction. The conditioned and unconditioned reflexes disappeared (Table 2 and Fig. 3).

In subsequent experiments, the unconditioned reflexes returned, but the conditioned reflexes did not (see Table 2).

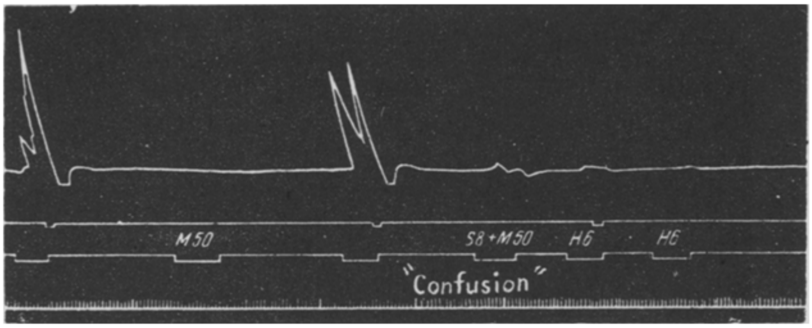

Fig. 3. Motor reaction on "confusion". Curves, from above downward: motor reaction, unconditioned stimulus marker, conditioned stimulus marker, time marker in seconds.

TABLE 1

Conditioned Reflex Reactions of the Dog Rex after Developing Differentiation and a Stereotype; Experiment No. 29

Time of day	Interval in minutes	Type of condition-ed stimulus	Number in se-quence	Time of action of condition-ed stimu-lus (in seconds)	Condi-tioned reac-tion	Time of action of condition-ed stimu-lus (in seconds)	Uncon-dition-ed re-action	Remarks
1	2	3	4	5	6	7	8	9
9 : 25	—	Horn No. 6	222	3	+	7	+++	
9 : 28	3	Horn No. 6	223	8	++	2	+++	Dog stands quietly
9 : 34	6	Horn No. 6	224	8	++	2	+++	The same
9 : 37	3	M-50	43	10	—	—	—	" "
9 : 43	3	Siren No.8	94	8	+++	2	+++	
9 : 45	3	The same	95	8	+++	2	+++	
9 : 49	3	M-50	44	10	—	—	—	Completely still
9 52	3	Horn No. 6	225	8	++	2	+++	Generalized motor reaction
9 : 55	3	The same	226	8	++	2	+++	
9 : 58	3	" "	227	8	++	2	+++	
10 : 01	3	Siren No. 8	96	8	+++	2	+++	
10 : 04	3	The same	97	8	+++	2	+++	

After "confusion", the oxygen requirement was less than in the control experiments, and fell during the course of 1 hour from 0.37 to 0.31 liters/kg (Fig. 1, c). In these experiments, gastric secretion was measured as well as the gaseous exchange.

As can be seen from Table 3, the classical food stimuli – bread, milk, and meat – also produced gastric secretion changes. While in the control experiments 14.7 ml of juice was secreted in 5 hours, during the development of conditioned reflexes this amount was increased by 9%; when differentiation was obtained the increase was 20%, and with "confusion" it was reduced by 9% (see Table 3).

When developing the positive defensive conditioned reflexes, the secretion of gastric juice was increased by 12% as compared with the control experiment values; when developing the negative conditioned reflex, the increase was 13%, and there was a reduction of 6% in the case of the "confusion". On days when the positive conditioned reflex to meat was being developed, the gastric glands showed a functional increase of 25%; with

TABLE 2

Conditioned Reflex Reactions of the Dog Rex at the First "Confusion"; Experiment No. 30

Time of day	Intervals (in minutes)	Type of conditioned stimulus	Number in sequence	Time of action of conditioned stimulus (in seconds)	Conditioned reaction	Time of action of conditioned stimulus (in seconds)	Unconditioned reaction	Remarks
1	2	3	4	5	6	7	8	9
9 : 32	—	Horn No. 6	228	3	+	7	+++	Stands quietly
9 : 35	3	The same	229	7	++	3	+++	The same
9 : 31	3	" "	230	8	+++	2	+++	" "
9 : 41	3	M-50	45	10	—	—	—	" "
9 : 44	3	Siren No.8	98	8	+ Total reaction	2	+++	The same
9 : 47	3	The same	99	8	+++	2	+++	" "
9 : 50	3	Siren No. 8 + M-50	1	10	Total reaction	—	—	First "confusion", looks round in various directions
9 : 53	3	Horn No. 6	231	8	—	2	+++	The same
9 : 56	3	The same	232	8	—	2	+++	Stands quietly
9 : 59	3	The same	233	8	—	2	+++	The same
10 : 02	3	Siren No. 8	100	8	—	2	+++	" "
10 : 05	3	The same	101	8	—	2	+++	" "
10 : 08	3	M-50	45	10	—	—	—	" "

differentiation, the increase was 30%, and the "confusion" caused a reduction almost to normal. In all these experiments there was scarcely any change in the acidity or in the latent period of the secretion (see Table 3).

After a three-month break in the summer, the experiments were repeated on the same dogs, and precisely the same results were obtained.

Our experiments showed that functional changes in the cerebral cortex (during the development of conditioned reflexes, after they had been established, and after the "confusion") cause well-marked changes in gaseous exchange and in gastric secretion. There is a smaller change in the acidity of the gastric juice.

When developing conditioned reflexes, before the conditioned linkages had become established, and while the cortical excitation was generalized, as a rule, the gastric secretion was considerably increased in response to all the food stimuli used (bread, meat, milk). The greatest increase in secretion occurred in response to meat (23-25%), as this was the strongest gastric juice stimulant. There was s simultaneous increase of 15% in the gaseous exchange rate.

To us, it seems that this increase in the functions described, which takes place during the initial phase of the development of conditioned reflexes, must be interpreted as being due to an irradiation of the cortical excitation occurring through the action of external stimuli on the lower subcortical centers.

This idea is supported by the fact that as the conditioned reflexes become more firmly established, the changes which occur become less marked, and finally the quantities measured return to their original values. According to the Pavlov school, this period corresponds to the concentration of excitation and to its equilibration with the inhibitory process.

TABLE 3

Dog Rex. Secretion of Gastric Juice in Response to 200 g of White Bread

Hours in sequence	Standard conditions: Time of juice collection from	to	amount of juice (in cm³)	acidity (in cm³ of 1/50 NaOH)	Development of positive conditioned reflex: hours in sequence	Time of juice collection from	to	amount of juice (in cm³)	acidity (in cm³ of 1/50 NaOH)	Development of negative conditioned reflex: hours in sequence	Time of juice collection from	to	amount of juice (in cm³)	acidity (in cm³ of 1/50 NaOH)	"Confusion": hours in sequence	Time of juice collection from	to	amount of juice (in cm³)	acidity (in cm³ of 1/50 NaOH)
1	10:30	11:30	5,1	4,67	1	11	12	5,4	5,6	1	10:45	11:45	4,8	5,7	1	10	11	4,9	4,7
2	11:30	12:30	3,4	5,70	2	12	13	5,0	6,55	2	10:45	12:45	5,3	6,2	2	11	12	3,5	5,75
3	12:30	1:30	3,0	5,03	3	13	14	3,1	5,8	3	12:45	1:45	3,6	6,2	3	12	13	2,4	5,40
4	1:30	2:30	2,2	4,3	4	14	15	1,6	5,5	4	1:45	2:45	2,6	5,6	4	13	14	1,7	4,8
5	2:30	3:30	1,0	1,3	5	15	16	1,0	4,9	5	2:45	3:45	1,4	5,1	5	14	15	0,8	4,4
Total			14,7					16,1 +9%					17,7 +20%					13,3 —9%	

The development of internal inhibition caused a still greater increase in gastric secretion (from 19 to 30%). When developing conditioned inhibitory reflexes, there is evidently at first a generalized cortical inhibition, and because this is widespread, the positive conditioned reflexes produce less effect.

On account of its inertia, a weak diffuse inhibition is maintained for a considerable time after the experiment, during the period of measurement of the gastric secretion. Because of the weakness of the inhibition, it does not irradiate into the lower subcortical regions, but acts by positive induction to increase their excitability, which leads to an increase in gastric secretion.

"Confusion" of the processes of excitation and inhibition in the cerebral cortex produced a directly opposite effect, i.e.,there was a marked reduction in both gaseous exchange and gastric secretion. The latter often fell to 9-10% below its original value. In this case, "confusion" caused a breakdown of conditioned reflex activity.

The development of an inhibitory condition in the cerebral cortex, following "confusion", causes an irradiation of this inhibition to the subcortical region, and this is evidently the reason for the reduced activity of the functions described.

From what has been said, we may conclude that when cortical function is disturbed, so also are the subcortical centers, and the condition of the latter in turn brings about changes in the rates of gaseous exchange and of gastric secretion.

SUMMARY

Experiments performed on dogs demonstrated that the change of the functional condition of the dog's brain cortex alters the gas exchange and the gastric secretion.

The gastric secretion to bread, meat and milk increases during the first day of formation of conditioned reflex associations. After the reflexes to the same stimuli are formed, both secretion and gaseous exchange drop to a normal level. The process of internal inhibition formation causes an even greater rise of gastric secretion and gaseous exchange. In neurosis, a considerable decrease of the above autonomic functions was noted.

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* In Russian.