DIFFERENCES IN THE NEUROCHEMICAL MECHANISMS OF CONDITIONING TO STIMULI OF DIFFERENT MODALITIES AT THE CAUDATE NUCLEUS LEVEL IN RATS

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Microinjection of noradrenalin into the head of the caudate nucleus in rats did not affect the latent period of avoidance conditioning or muscle tone but inhibited motor activity, reduced the number of taps, and significantly increased the amplitude and latent period of the conditioned food-getting reflex. Local microinjection of serotonin into the neostriatum did not affect the latent period of the conditioned avoidance reflex and did not change the motor activity but it reduced the latent period and the number of taps in the conditioned food-getting response and increased its amplitude significantly. Dopamine inhibited the conditioned food and avoidance reflexes but significantly activated the spontaneous motor activity of the rats. The results are evidence of differences in the neurochemical mechanisms of conditioned reflexes to stimuli of different modalities closed at the caudate nucleus level in rats.

KEY WORDS: caudate nucleus of rat brain; biogenic amines; conditioned reflexes.

The participation of the caudate nuclei in the integration of food and avoidance reflexes is now regarded as firmly established [2, 3, 6]. The neurochemical mechanisms of the neostriatum responsible for conditioned-reflex behavioral responses have not, however, been fully explained. Despite the high sensitivity of single neurons of the caudate nucleus to microapplication of catecholamines [12] and despite the discovery of large quantities of dopamine (DA), noradrenalin (NA), and serotonin (5-HT) in the basal ganglia [13-15], there is still no information in the literature on the role of the monoamines of the corpus striatum in the mechanisms of closure of the temporary connection and their effect on positive and negative conditioned reflexes. The suggestion has been made that excitation or inhibition of adrenergic structures of the neostriatum can substantially modify the program of behavior and modulate the quantitative characteristics of conditioned reflexes [7].

The object of the present investigation was to study the functional role of NA, DA, and 5-HT, injected into the head of the caudate nucleus in rats, in conditioning to stimuli of different biological modality.

EXPERIMENTAL METHOD

Experiments were carried out on two groups of sexually mature male rats. Higher nervous activity in group 1 was investigated by the motor-food method [4] in a viniplast chamber with a feeding bowl separated from the body of the cage by a plastic door. The conditioned stimulus (a buzzer), 10 sec in duration (acting alone for 5 sec) was presented five times every day at intervals of 60 sec. Unconditioned reinforcement consisted of balls of moist meat and bone meal with the addition of bread. Throughout the period of the investigation the rats were kept on a strict diet. Every day between 2 and 3 p.m. the animals received dry food (bread). Thirty minutes later the dry food was taken away and only liquid was left (milk). To record the motor-food conditioned reflexes (FCR) to the conditioned stimulus quantitatively (at the time when

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TABLE 1. Effect of Monoamines Injected into Caudate Nucleus on CAR, Muscle Tone, Motor Activity, and Signal Cycle of FCR (M ± m)

Substance injected	Dose of base (in μg)	Latent period of CAR (in sec) 30 min after injection of preparation	Motor activity	Muscle-relaxing action (% of animals falling off bar)	Signal cycle of food conditioned reflex 30 min after injection		
					latent period of reflex (*in* sec)	amplitude of reflex	number of taps
Bidistilled water (control)	—	1,09±0,094	50,4±3,44	0	+(0,02±0,03)	+(14,8±1,34)	+(1,7±0,14)
Noradrenalin	3	1,06±0,076	33±3,64*	0	—(0,05±0,09)	+(46,3±7,81)*	—(0,38±0,22)*
	5	1,09±0,05	30±3,83*	0	+(0,33±0,05)*	+(47,8±10,17)*	—(1,8±0,64)*
Dopamine	5	2,4±0,179*	73±3,68*	0	+(0,64±0,068)*	—(4,6±2,267)*	—(2,4±0,4)*
Serotonin	5	1,07±0,067	45,8±4,69	0	—(0,09±0,034)*	+(33±5,879)*	—(2,2±0,52)*
	10	2,72±0,153*	32±3,22*	20	+(1,06±0,192)*	—(57,7±8,518)*	—(4,6±0,686)*

Legend. +) Increase −) decrease in parameters of signal cycle of FCR. Parameters differing by a statistically significant degree ($P < 0.05$) from the control are marked by an asterisk.

the rat opened the door and took the food balls) a recording system similar in principle to that used for investigations of this type [5] was used but with a modified electronic circuit incorporating decatrons, by means of which three parameters of the motor conditioned reflexes could be recorded: the latent period of the reflex (the time from applying the buzzer to the tap of the door), the amplitude of the reflex (the aggregated angle of opening of the door in response to the conditioned stimulus), and the number of taps (the number of movements of the animals aimed at opening the door).

In the animals of group 2 a conditioned-avoidance response (CAR) was produced by the method described earlier [8]. After consolidation of the FCR and CAR, the animals were anesthetized with ether, and with reference to the atlas of the rat brain [10] a guide cannula was inserted by means of the SÉZh-2 stereotaxic apparatus into the dorsal part of the head of the right caudate nucleus, through which solutions of the test substances in a volume of 3-5 μl could be injected by means of a microinjector. The effect of the monoamines on the FCR was estimated from the parameters recorded as described above, by assessing their changes 30 min after injection of the catecholamines and serotonin into the caudate nucleus. The numerical results reflecting changes in the parameters of FCR were analyzed by the difference method by subtracting from the averaged experimental values obtained during a conditioning cycle the corresponding averaged control values recorded in response to microinjection of bidistilled water (5 μl) into the corpus striatum. As suitable criteria for assessing the selective action of NA, DA, and 5-HT on the CAR by the method described above [8], changes in the latent period of the reflex, the muscle tone, and spontaneous motor activity (SMA) of the rats caused by local microinjection of the monoamines into the neostriatum were studied. The region of the microinjection was identified by examining serial histological sections through the rat brain.

EXPERIMENTAL RESULTS AND DISCUSSION

Microinjection of NA into the head of the caudate nucleus (3 μg) was not followed by changes in the latent period of FCR or CAR, but the number of taps was reduced and the SMA of the rats was significantly restricted. NA in a dose of 5 μg had a similar effect on these parameters of both behavioral responses, but it significantly increased the latent period of the motor-food reflex only (Table 1). When the results are compared it must be remembered that the depriming effect of NA on the latent period and the number of taps of the FCR was unconnected with inhibition of the SMA of the rats. This was shown by the fact that microinjection of this catecholamine (3 and 5 μg) into the neostriatum did not change the muscle tone of the animals and it increased the amplitude of the motor-food reflex by a statistically significant degree (Table 1), a parameter regardable as an indicator of motivational excitation [9] for it reflects the total effort of the animal made in response to the conditioned stimulus. The experimental results are evidence of the functional inequality of the neurochemical mechanisms of the caudate nucleus producing the two types of conditioned-reflex responses. Participation of NA is evidently not essential for the production of the reflex to a biologically negative stimulus, but this amine has an inhibitory effect on excitation of a biologically positive modality resulting in the formation of the FCR at the level of the corpus striatum.

Local microinjection of DA (5 μg) into the structures of the caudate nucleus more than doubled the latent period of CAR and led to a considerable increase in the latent period of the FCR. Meanwhile, this catecholamine appreciably reduced the number of taps of the food-getting reflex, but it significantly stimulated the SMA of the rats (Table 1). The depriming effect of DA on FCR could be due to a diminution of food motivation, for microinjection of this catecholamine into the neostriatum causes a significant decrease in the amplitude of the reflex. Meanwhile, analysis of the data indicates the selectivity of action of DA on the neurochemical mechanisms forming temporary connections between the trigger stimulus and the acquired motor-food or avoidance response. This is confirmed by the stimulant effect of DA on the SMA of the rats (Table 1) and by a special series of experiments which showed that the decrease in the number of taps and the action of DA in increasing the latent period of both FCR and CAR were significantly reduced by preliminary microinjection of haloperidol (3 μg), but not of phentolamine (3 μg), into the caudate nucleus. However, only phentolamine (but not haloperidol) abolished the depriming effect of NA on the number of taps and on the latent period of the FCR. These facts suggest that afferent excitation, varied in its biological modality, is closed through the dopaminergic neuronal systems of the caudate nucleus, with the participation of which DA exerts its inhibitory effect on both motor-food and conditioned-avoidance reflexes. Electrophysiological experiments demonstrating the hyperpolarizing effect of microphoretically applied DA on single neurons of the caudate nucleus [12] and experiments demonstrating the inhibitory effect of DA on the conditioned-reflex activity of cats [16] confirm this conclusion.

Unlike NA and DA, 5-HT (5 μg) facilitates FCR, as is manifested by substantial shortening of the latent period of the reflex. Meanwhile, this amine did not affect the latent period of the CAR and did not change the SMA of the rats, although it significantly reduced the number of taps and, at the same time, increased the amplitude of FCR. In a dose of 10 μg, 5-HT had a depriming effect on all the parameters of the FCR signal cycle recorded and it inhibited CAR. However, the inhibitory effect of 5-HT on the higher nervous activity of the rats was nonspecific and was evidently due to inhibition of the segmental apparatus, for it correlated with the muscle-relaxant action and the marked limitation of SMA of the rats (Table 1).

The experimental results described above show that, like noradrenergic mechanisms, the serotoninergic mechanisms of the neostriatum participate in the formation of food, but not of conditioned-avoidance, reflexes. This conclusion is in agreement with experiments in which a high concentration of 5-HT was found in the tissues of the neostriatum [15] and in which the synthesis and more rapid liberation of this amine from the synapses of the rat caudate nucleus were found to occur in response to electrical stimulation of the corpus striatum or to injection of amphetamine [11].

To sum up the experimental results it can be concluded that subcortical influences, specific in their biological modality, on the cerebral cortex [1] are effected with the participation of various neurochemical mechanisms that give rise to conditioned-avoidance and motor-food reflexes at the level of the caudate nucleus in rats.

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