CHANGES IN LEARNING AFTER PINEALECTOMY IN RATS

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The pineal gland is widely regarded as an organ transmitting environmental influences through the visual and olfactory pathways to the internal medium of the body [4-6]. However, under the influence of pineal hormones changes take place in the electroencephalogram and parameters of behavioral responses [2, 4, 10].

The aim of this investigation was to analyze changes in formation and recall of adaptive responses in pinealectomized animals in order to clarify the precise role of the pineal gland in learning and memory processes.

EXPERIMENTAL METHOD

Experiments were carried out on 118 sexually mature rats, on which pinealectomy was performed by a modified method in [9]. A session of learning a locomotor avoidance response (LAR) consisted of electrodermal stimulation (EDS) of the animals' limbs before moving into the safe compartment. The criterion of learning was the attainment of 70% of correct responses. The conditioned active avoidance response (CAAR) was formed to an acoustic stimulus (5 stimuli/sec). The conditioned avoidance response was formed on the basis of visual differentiation in a Y-maze [3]. The "response to place," on the basis of spatial differentiation (RDS) was formed in a 16-door maze [1]. Learning processes were tested in intact and pinealectomized rats and rats undergoing a mock operation 10 and 20 days after the operation. Indices of preservation of the established responses were determined in 20 tests 1 and 7 days after the training session. Epithalamin, containing a group of pineal peptides, was injected intraperitoneally in a dose of 0.5 mg/kg for 5 days.

TABLE 1. Effect of Pinealectomy and of Epithalamin on Time Course of Learning Conditioned Avoidance in a Y-maze (M ± m)

Group of animals	Number of tests used in learning		Index of preservation of responses, %	
	Learning up to the criterion	appearance of reflex twice in succession	after 24 h	after 7 days
Intact rats	33,3±3,4	14,3±1,2	59±4	67±8
Animals after injection of epithalamin (0.5 mg/kg)	20,5±2,5*	12,6±1,2	61,5±4,5	68±7
Rats undergoing mock operation	31,9±3,8	13,3±2,1	59,0±4,5	66±8
Pinealactomized rats (10th-20th day)	49,3±7,2*	5,2±1,4*	66,7±5,1	76±4

Legend. Here and in Tables 2 and 3: *$p < 0.05$.

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TABLE 2. Changes in Parameters of Formation of "Response to Place" in Pinealectomized Rats (M ± m)

Group of animals	No. of tests		Search for safe place in the maze			
			1st test		2nd test	
	learning up to the criterion	appearance of reflex for the first time	time, sec	number of movements	time, sec	number of movements
Intact rats	26,2±1,1	18,9±0,8	88,4±4,9	16,3±1,4	30,4±2,8	12,2±1,1
Animals after injection of epithalamin (0.5 mg/kg)	22,7±2,2	20,2±1,1	104,5±9,1	20,7±2,2	32,7±4,5	14,9±1,9
Rats undergoing mock operation	29,8±2,7	22,2±1,8	117±11,2	19,6±3,1	22,3±3,0	13,3±0,9
Pinealectomized rats:						
10th-20th day	54,2±3,6*	39±3,9*	103,6±11*	53,7±8,1*	48,8±7,5*	33,5±2,5*
21st-30th day	68,7±5,6*	54,9±5,2	203,8±31*	68,2±11*	67,1±12,5	38,4±4,9*

EXPERIMENTAL RESULTS

Parameters of learning the main types of responses 10 days after pinealectomy differed from those in intact rats and in rats undergoing the mock operation. After the first tests in the training session the time taken by pinealectomized rats to form LAR was shorter than in the control groups, and the criterion of learning was reached earlier (3 ± 0.5 and 11 ± 0.9 tests respectively). Acceleration of the process of learning CAAR in the pinealectomized rats was expressed as shortening of the learning times. After only 62.2 ± 11 tests the 70% level of conditioned responses was achieved, whereas in the control there were 7.4 ± 0.9 responses in the training session. Conversely, after 7 days the index of preservation of CAAR was 25.4 ± 6%, or 22% lower than in the control.

Formation of conditioned avoidance on the basis of discrimination between visual stimuli was disturbed after pinealectomy in the first training session. The criterion of learning was reached by the pinealectomized animals after 49.3 ± 7.2 tests and by the intact rats after 21.9 ± 3.8 tests ($p < 0.1$). Repeated formation of the avoidance response next day revealed no differences between the groups of rats. Very small differences were found (Table 1) 7 days after the training sessions when testing preservation of engrams of the response produced (67 ± 8 and 76 ± 4% respectively).

After pinealectomy the "response to place" based on a fourfold choice of the direction of movement in a 16-door maze, was distinctly delayed. Compared with rats undergoing the mock operation and intact rats, these animals required 58.5-69% more tests to achieve the criterion of learning. Analysis showed that the first response of spatial differentiation was formed later. The course of the process of consolidation of RSD showed no differences (Table 2). The pinealectomized rats used more searching movements in the first tests to look for a safe place in the maze. Consequently, after the operation the use of acquired experience to contract the zone of searching, which was a feature of the intact animals, was adversely affected. Indices of preservation of RSD 24 h after the learning session were identical in value.

Holding the training session in the later stages after pinealectomy (after 20 days) was accompanied by more marked disturbances of the learning of the "response to place". The times required to reach the criterion of learning were increased by 131%. The later appearance of the first correct response was accompanied by a twofold increase in the searching time for the safe compartment, and a threefold increase in the number of searching movements (Table 2).

Analysis of parameters of modification of spatial differentiation (Table 3) shows that the phenomenon of "positive transfer" of acquired experience to the solution of similar problems was preserved in both intact and pinealectomized animals, in the form of a 2.2 times faster rate of modification in three or four series of experiments. During the change from a zigzag strategy of movement toward the safe compartment to linear movement, modification took place with "negative transfer" of experience of the established set. The intensity of "negative transfer" in five or six series of modifications was disturbed in the late stages (20 days) after pinealectomy.

Injection of epithalamin into intact animals accelerated the formation of a conditioned response of visual differentiation and the "response to place" in the course of 5 days (Tables 1 and 2). The results indicate that pineal peptide regulators are involved in the learning of visual and spatial differentiation. This hypothesis is supported by the similarity of one of the pineal peptides [7, 8] to vasopressin and oxytocin, which have antiamnesic properties

TABLE 3. Effect of Pinealectomy and Epithalamin on Modification of Spatial Differentiation (M ± m)

Group of animals	Number of tests used to modify responses		
	1—2 tests	3—4 tests	5—6 tests
Intact rats	39,5—2,5	20,2—2,2	29,1—2,1
Animals after injection of epithalamin (0.5 mg/kg)	32±1,8*	25±1,4	19,1±1,5*
Rats undergoing mock operation	43,2±3,1	24,6±2,8	35,8±3,1
Pinealectomized rats:			
10th-20th day	90,2±7,9*	39±6,8*	50,9±5,0*
21st-30th day	104,8±9,7*	43,7±1,9*	35,2±3,9

and modulate learning processes [3, 9]. It is possible that the unique ability of the pineal gland to transform an external environmental influence into a hormonal response, whose peptide components selectively modify the functional state of brain formations, is the leading mechanism of the realization of its action on processes of learning adaptive skills.

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