

ON THE RELATIONSHIP BETWEEN THE FUNCTIONAL AND STRUCTURAL  
DEVELOPMENT OF THE CEREBRAL CORTEX IN THE PROCESS OF  
ONTOGENESIS

COMMUNICATION I. THE ONTOGENIC DEVELOPMENT OF CONDITIONED REFLEX ACTIVITY IN RABBITS

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We undertook to find the relationship between the functional and structural development of the cerebral cortex in rabbits in the course of ontogenesis. This problem was solved by comparing the data obtained from physiological and histological studies.

In this article, we present the results of experiments made to determine the earliest time during postnatal development that it is possible to produce conditioned reflexes in rabbits.

In order to obtain data as conclusive as possible, we used both the food and defense methods of producing conditioned reflexes; a conditioned reflex was developed to olfactory, sound, tactile, thermal and light stimuli.

EXPERIMENTAL METHODS

The food conditioned reflexes were developed according to V. A. Troshikhin's method [5], so modified that it was possible to develop conditioned reflexes from other analysors as well as the olfactory and that the reflexes could be recorded as objectively as possible.

Several days before parturition, the mother rabbit was put into a large, specially made box, with two compartments — a nursery compartment, where the mother rabbit made a nest and where the baby rabbits were born, and a compartment for the mother rabbit. The first compartment of the box had a movable floor, placed on four rubber balloons which were attached to a Marey's recording cylinder. This arrangement permitted the fluctuations of the floor caused by the movements of the rabbits in the nest to be recorded on a kymograph.

At the same time, the rabbits were watched through a specially made small window, so that their reactions could be described in detail.

The mother rabbit nursed the young rabbits once a day. She was removed from the nest every evening so that the baby rabbits might learn to associate their feeding with the action of the various conditioned stimuli. When the mother was put back into the nursery on the following morning, she began at once to feed the baby rabbits. Experiments with the development of conditioned reflexes were done on 13 litters of rabbits.

In order to develop the conditioned reflexes, the mother's nipples were smeared with some sort of odiferous substance (eau de cologne, camphorated oil, etc.) before nursing.

The experiments showed that this type of conditioned reflex develops very quickly — during the very first feeding. These data agree with the results of similar studies conducted on puppies by V. A. Troshikhin [5].

The conditioned reflex could be determined in two ways. 1) When a conditioned reflex was present and food excitability was sufficiently high, the following typical reaction was caused in the rabbits by the introduction into the nest of a cotton wad dipped in the odiferous substance. The rabbits went into a state of great motor excitement, which was manifested by complex movements of their heads and bodies (resembling those which are performed when the rabbits are searching for their mother's nipples), by their mouths opening and making sucking motions while they lapped and rolled over on their backs, and finally by the characteristic action of "licking their chops", which we believe to be one of the most specific signs of the food reflex. 2) A baby rabbit was taken out of the nest, and a palm smeared with the appropriate odiferous substance was held up to it. When a conditioned reflex was present, this action caused great excitement in the rabbit; he crawled up to the palm, raised his head and began to lick the hand, moving his head as though looking for the nipple. The most typical reaction was the rolling over of the rabbit on its back, as rabbits naturally nurse lying on their backs (Fig. 1).



Fig. 1. Conditioned food reflex to smell. A palm smeared with "Chypre" eau de cologne, the odor of which was a conditioned food stimulus. Rabbits rolling over on their backs in the typical fashion.



Fig. 2. Conditioned food reflex to air jet. Rabbit sucking the tip of a bulb producing the air jet.

In control experiments, it was established that the use of the same stimuli before the development of the conditioned reflexes did not cause the typical food reaction described above and sometimes caused a negative motor reaction.

Experiments with the development of a conditioned reflex from the skin analyzer were done on 10 litters of rabbits; 8 of these 10 litters were used to develop a reflex to tactile stimulation, and 2 to develop a reflex to thermal stimulation.

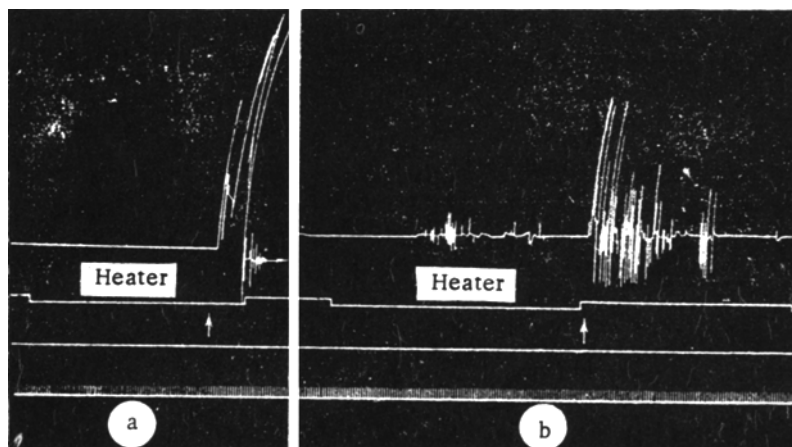


Fig. 3. Kymograms of experiments with the development of a conditioned food reflex to heat.

a) 10th experiment, no reflex; b) 11th experiment, expressed food reflex. Curves (from top to bottom) show: recording of rabbits' movements, indication of conditioned stimulus (heater);  $\uparrow$  — unconditioned stimulus (mother's arrival and feeding), indication of time in 1-second marks. Sharp rise in the motion curve — arrival of mother in nest and beginning of nursing.

To develop a conditioned reflex from the skin analyzor, an air jet (tactile stimulus) was blown into the nest before feeding, by means of a rubber bulb or electroventilator, or a special heater was put into the nest (thermal stimulus). In the first experiments, the conditioned stimulus was used first for 10-15 seconds, then the time was increased to 30 seconds and in some experiments to 1 minute.

In the various series of experiments, the conditioned stimulus was either used for 10-15 seconds during feeding, as in the majority of cases, or for the entire feeding period (3-5 minutes).

After the conditioned reflex had developed, the use of these stimuli alone caused the typical motor reaction — great general excitement in the rabbits. The rabbits ran about the nest as though looking for their mother, made sucking motions, "licked their chops" and crowded up to the place where the conditioned stimulus was being produced. When the air jet was being used, for example, the rabbits gathered at its source and sometimes even sucked at the tube from which the air issued (Fig. 2). When the heater was being used, the rabbits licked the screen partitioning the heater from the nest. These observations can be compared with the known fact that a dog will lick a lamp, the light of which is a conditioned food stimulus for it.

The food reaction described could also be reproduced outside the nest; in some of the experiments, we used a motion picture camera to record the reaction.

The presence of feeding motions (sucking, lapping and chop licking), as well as the stability and force of the food reaction clearly distinguished this reflex from other types of reactions, the orientation reflex, for example, which was observed with the first uses of the conditioned stimulus or with the use of other stimuli.

Experiments developing a conditioned reflex to sound were done on 11 litters of rabbits. To develop this conditioned reflex, a sound signal was turned on before feeding (electric oscillator, 500 oscillations per second). The experimental conditions and the nature of the conditioned-reflex food reaction were the same as those described with the development of a conditioned reflex from the skin analyzor.

We did not conduct specific experiments with the development of conditioned food reflexes to light, but a conditioned food reflex of this type did develop in the rabbits at a definite age, since their nest was lighted before every experiment.

To ascertain the stage in postnatal development when conditioned reflexes begin to develop, we conducted experiments from the day the rabbits were born. One experiment was done a day on each litter (the mother rabbit suckled the litter only once a day). A reflex was developed to one stimulus at each experimental stage.

The method we selected allowed the conditioned reflexes to develop under conditions as physiological as possible. The possibility of external inhibition was almost completely excluded, since the rabbits were not taken out of the nest. We used a reaction natural to the rabbits (looking for the mother's nipple) as the conditioned reflex reaction. All these factors favored the rapid development of stable conditioned reflexes, which made it possible to determine fairly exactly the time at which the corresponding analyzor became functionally mature. The disadvantage of the method we used was the impossibility of making an exact quantitative evaluation of the conditioned reflex. Moreover, the kymographic recording only showed the reaction of the litter as a whole.

Besides the food conditioned reflexes, conditioned defense reflexes to sound and light stimuli were also developed in the rabbits. The method used for this purpose was analogous to that described by A. B. Kogan and S. N. Shchitov [2].

## EXPERIMENTAL RESULTS

The experiments conducted showed that there were differences of 1-2 days in the times at which the conditioned reflexes developed in both the different litters of rabbits and the different rabbits of one litter. The data presented for each experimental series are the average for all the experiments.

Conditioned food reflexes to olfactory stimuli could be developed from the first day after birth.

The conditioned food reflexes from the skin analyzor to both the tactile and thermal stimuli began to appear the 10th day after birth (Fig. 3). The conditioned reflexes were still unstable and did not always appear at this stage; the most pronounced aspect of the reaction was that pertaining strictly to food (sucking motions, et al.), while the general motor reaction was more weakly expressed. The reaction only began to acquire greater stability on the 13th day after the rabbit's birth, when all the aspects of the reaction became clearly expressed. Condi-

tioned food reflexes to sound stimuli began to develop 10-11 days after birth, becoming more stable the 13th day.

The defense conditioned reflexes to sound began to develop at about the same time as the food conditioned reflexes, i.e., 10 days after birth.

These data agree with the results obtained by A. A. Volokhov [1] and G. A. Obraztsova [4], who studied the development of a conditioned rejection (shaking off) reflex to sound in rabbits.

Conditioned food reflexes to light stimuli began to develop on the 13th day after birth (reflexes unstable). More stable reflexes began to develop the 15th day. These data agree with the results of the experiments conducted with the defense method.

Unconditioned food and defense reflexes appeared in the rabbits from the moment of birth. Orientation reactions to the tactile, sound and light stimuli appeared before conditioned reflexes could be developed to these stimuli (on the 1st, 7th and 10th days after birth, respectively). The experiments show that the times at which conditioned reflexes develop depend on the times at which the cortical centers of the appropriate analysors, which mature later than the subcortical formations, achieve functional maturity; this fact agrees with data obtained from research on puppies [3, 6].

#### SUMMARY

It was established in experiments on rabbits that conditioned food reflexes to olfactory stimulation commence to develop from the very first day after birth. Conditioned food reflexes to tactile, thermal and sound stimulations develop from the 10th to 13th day. Reflexes to light stimulations begin to develop from the 13th to 15th day after birth. Conditioned defense reflexes to sound and light develop at the same periods as the conditioned food reflexes to these stimulants.

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\* In Russian.