THE EFFECT OF PROPRIOCEPTIVE REFLEXES ON THE HEART. CERTAIN PROPERTIES OF PROPRIOCEPTIVE CONDITIONED-REFLEX INFLUENCES ON THE HEART

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(Received March 17, 1956. Presented by Academician K. M. Bykov)

The change in heart activity caused by muscular work has been observed in numerous research works. Individual experimenters [1,4,6,9,10,13], through short experiments, have established proprioceptive influences on the heart, realized through the mechanism of unconditioned reflexes. Recent works have shown the possibility of forming conditioned proprioceptive reflexes on the heart in animals and man [2,3,5,7,8,12,18,19].

We have not, however, found in the literature any systematic description of the properties of the conditioned reflexes whose formation is based on unconditioned proprioceptive reflex influences on the heart.

Therefore, the first task in our study investigating proprioceptive influeces on the cardio-vascular system was to determine the properties of these condioned reflexes.

EXPERIMENTAL

The work was done on five male dogs. The experimental method was as follows. We used a physical (static) load as an unconditioned proprioceptive stimulus, placing the load on the back of a benched dog. The load weighed 80% of the animal's weight. Heart activity was recorded with an electrocardiograph; electrocardiograms in the three standard leads were recorded from the extremities. We used a metronome of 120 beats per minute (M120) as a positive condioned stimulus and a metronome of 60 beats per minute (M60) as a negative. The experiments were done in an ordinary laboratory room and in a conditioned reflex chamber.

Earlier [14], we found that a stable electrocardiogram is established for a given position of a dog's body after the reflexes to environment are extinguished. When no stimuli were used, the dogs' electrocardiograms remained essentially unchanged for over two years after their stabilization. In spite of this, in evaluating various influences on an animal's body, we started with the electrocardiographic background for that day rather than with the already established background electrocardiograms, so that, each time, the experiments began and often concluded with an electrocardiographic recording made without the influence of stimuli. This showed us that, in the dogs, there were respiratory arrhythmia and slight fluctuations in the rhythm, voltage, systolic index and other elements of the electrocardiogram.

In most cases, we used one reinforcement the day of the experiment, occasionally two, and in rare cases, more.

After recording the background electrocardiogram, we tested the effect of the conditioned stimulus alone, then that of the unconditioned stimulus alone, and finally at the end of the experiment, observed the effect of a combination or combinations of the conditioned and unconditioned stimuli. Sometimes, the effect of the conditioned stimulus alone was tested at the end of the experiment. The reinforcement was not used when testing the isolated effect of the positive conditioned stimulus on the animals.

The acting time of the unconditioned stimulus was 4 minutes and, in certain series of observations, 30 seconds and 1-2 minutes. The acting time allotted to the positive conditioned stimulus was, in most cases, the

same as that of the unconditioned stimulus.

We observed changes in the animal heart activity during the imposition of the static load and for 3-4 minutes after removal of the load. Having established this fact, we recorded electrocardiograms 30 seconds, 1, 2 and etc. minutes after the stimulating action had begun and 30 seconds, 1, 2, 3 and 4 minutes after the action of the stimuli had ceased, in order to trace the dynamics of heart activity change. Therefore, the use of the next stimulus was only possible 5 minutes after the action of the preceding one had ceased.

EXPERIMENTAL RESULTS

After having established stable electrocardiograms for the dogs, we developed conditioned reflexes based on the proprioceptive unconditioned reflexes on the heart.

Under conditions of an ordinary laboratory room, a positive conditoned reflex on the heart was formed after 6-10 combinations of the conditioned and unconditioned stimuli (Fig. 1), while fewer combinations of the stimuli were needed to form the conditioned reflex under conditions of a conditioned reflex chamber.

The clearest index of the heart activity changes caused by the static load was the change in rhythm; the number of cardiac contractions per unit of time increased considerably, and the respiratory arrhythmia usually disappeared. Other electrocardiogram elements also changed: the voltage of the positive waves (P and R) first decreased, then increased (at the moment when the conditioned stimulus fully reproduced the effect of the physical load); the voltage of the negative waves (Q and T) decreased; the width of the P wave first increased, but returned to its original size as soon as the conditioned reflex was fixed; the size of the sector P-Q now increased, now decreased, finally becoming shorter; the complex QRS became broader and the interval R-T shorter; the electric ventricular systole decreased by 0.04-0.05 seconds (from 0.22 to 0.17-0.18 seconds), and the systolic index grew due to the reduction of the distance R-R. All the electrocardiograms changes caused by the action of the unconditioned stimulus were almost completely reproduced by the action of the conditioned stimulus, with slight differences in different dogs.

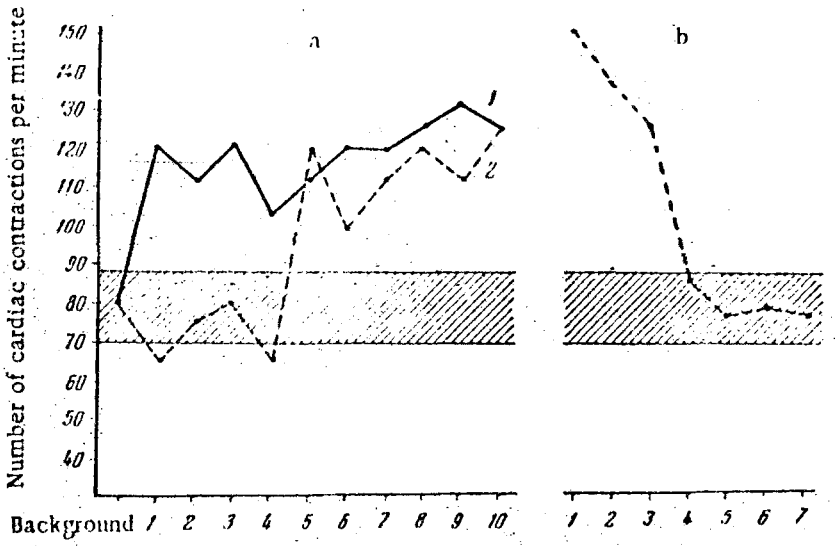

Fig. 1. Formation (a) and extinction (b) of proprioceptive conditioned reflex on heart in the dog Jack.
Along the horizontal – background and ordinal numbers of reinforcements or non-reinforcements of conditioned stimulus by unconditioned. Shaded strip – normal range of rhythm; 1) greatest rhythm changes under the influence of the physical load in the given experiment; 2) corresponding rhythm change caused by the action of the conditioned stimulus alone.

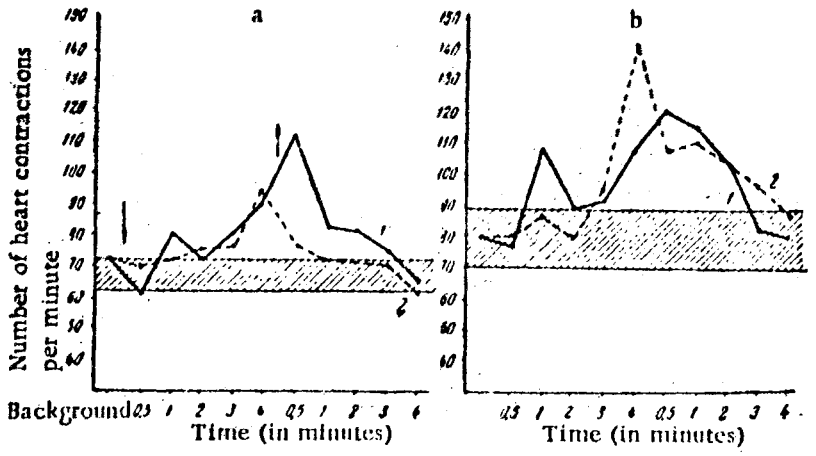

Fig. 2. Conditioned stimulus reproduction of the effect of the unconditioned stimulus. In the dog Treasure (a), in the dog Jack (b). Arrow down – beginning of stimulus action; Arrow up – cessation of stimulus action; 1) unconditioned reflex; 2) conditioned reflex.

The graphs included showing the rhythm changes in heart activity caused by the action of the unconditioned and conditioned stimuli were made from experiments on the dog Treasure after 20 combinations and on the dog Jack after 16 combinations of the stimuli (Fig. 2). They show that the conditioned stimulus effected exactly the same type of change in the heart activity as did the physical load. This applies to all the elements of the electrocardiogram. With the use of the static load, the maximal changes occurred during the period immediately after the action of the unconditioned stimulus had stopped, but, with the use of the conditioned stimulus, they occurred during the last minute of the stimulus action. However, this only characterized the given phase of the animal's manifestation of a reaction to the unconditioned and conditioned stimuli, and was not invariably observed.*

The fixed proprioceptive conditioned reflexes on the heart remained in the animals for a long time after the conclusion of the experiments. We twice interrupted the experiments after the fixation of the conditioned reflexes in two animals: the first interruption was 70 days for the dog Treasure and 85 days for the dog Jack; the second interruption was 135 days for both animals. Testing the effect of the conditioned stimulus after such interruptions showed that this stimulus caused the same changes in heart activity as before the experiments were interrupted. We must mention that the experimental set-up had a most marked effect on heart activity in these experiments. Noticeable changes in the animals' electrocardiograms made after the interruption were observed after the influence of the former experimental conditions alone, without the use of the positive conditioned stimulus. Consequently, the whole complex of the experimental conditions served as a conditioned stimulus to the animals, as well as the M120, even though reflexes to the surrounding had been eliminated before the work was begun, and changes in the animal heart activity had not been effected by the experimental set-up before the interruption of the work.

Although the fixed conditioned reflexes on the heart remained for several months after the dog's removal from the work, their active elimination was quickly accomplished. We found that it sufficed to place the animal a few times in the conditions of the earlier experiments and use the conditioned stimulus without reinforcement. In order to eliminate the proprioceptive conditioned reflexes, we put the animals on a bench for 15-20 minutes in the same room where the conditioned reflexes had been formed, and, once a day, used M120 without the reinforcement of the static load. After this had been repeated 3-4 times, the heart activity of the dog Jack returned to the original level under these conditions (see Fig. 1). The conditioned reflex was eliminated just as quickly in the other dogs.

The extinguished proprioceptive conditioned reflexes on the heart could be restored in the dogs after 1-2 combinations of the conditioned and unconditioned stimuli.

* See Sapov, I. A., Byull. Eksptl. Biol. i Med., 1957, Vol. 43, No. 1, p. 14.

An inhibitory conditioned reflex was formed in the animals after 1-4 uses of the differentiation stimulus. The first use of M60 on the dog Treasure retarded the rate of heart activity and prolonged the electric systole of the heart, as shown by the expansion of the complex QRS.

Figure 3 shows the changes in the rhythm of heart activity caused by the action of the positive and negative conditioned stimuli.

The second use of M60 (in the following experiment) caused no change in the animal's heart activity. Later, in all of the experiments, M60, used once, appeared firmly fixed as a differentiation. The third group of graphs (Fig. 3) shows the changes in heart activity occurring after many uses of the stimuli.

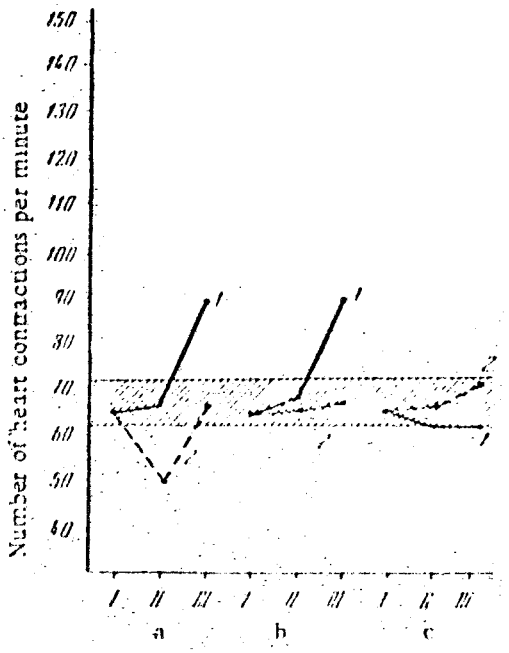

Fig. 3. Differentiation formation in the dog Treasure.
I) background; II) during the stimulus action; III) after the stimulus action. 1) positive conditioned stimulus (M120); 2) negative stimulus (M60). a) after one combination of M120 with the static load during the restoration of the conditioned reflex, the first use of M60; b) after 6 combinations of M120, the second use of M60; c) after 69 combinations of M120, the 15th use of M60.

These then were the results of some of the experiments conducted in order to examine certain properties of proprioceptive conditioned reflexes on the heart. They indicate the importance of influences from the proprioceptors in the adaptation of the heart activity to the ever changing conditions of natural existence and, possibly, the leading role played by proprioceptive influences in the regulation of heart activity.

Proprioceptive conditioned reflexes on the heart are quickly formed; the effect of the unconditioned stimulus is completely reproduced by the conditioned stimulus; these reflexes persist for a long time after the removal of the animal from the experimental surroundings, but can be quickly eliminated as well as quickly restored; a differentiation is formed after several uses of a nonreinforced stimulus — all these are properties of natural conditioned reflexes. The animal encounters daily many stimuli which invariably cause motor reactions, which, in turn, specify changes in the activity of the heart. A great many natural conditioned reflexes can be formed on the basis of unconditioned proprioceptive reflex effects on the heart. By the formation of one or two artificial proprioceptive reflexes, we add but little to the great quantity of natural proprioceptive conditioned reflexes. However, by this method, one can determine certain of their characteristics and, therefore, begin to understand the remarkably varied changes in heart activity which are observed both with the influence of stimuli directly causing a motor reaction and with the action on the body of all the environmental conditions under which the action of the stimuli occurs or occurred.

SUMMARY

Proprioceptive conditioned reflexes on the heart were studied in 5 dogs with the aid of electrocardiography. These reflexes are formed after 6-10 combinations of conditioned and unconditioned stimulations and are preserved for a long time in the intervals between experiments. Their frequency is actively increased, if not reinforced, 3-4 times and are restored after 1-2 combinations.

Differentiation takes place after 1-4 stimulations. These properties show the leading role of proprioceptive conditioned reflexes in adaptation of the heart activity to the changing conditions of the body.

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* In Russian.