THE CONDITIONED REFLEX REGULATION OF THE BLOOD PRESSURE

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(Received December 22, 1957. Presented by Academician K. M. Bykov)

Changes in the blood pressure during muscular activity are well known. As long ago as in 1883, I. P. Pavlov [7] observed by recording the blood pressure of dogs during experiments of long duration that every movement of the animal is accompanied by a brief variation in the level of the blood pressure.

In the last ten years it has been shown by Soviet physiologists [1, 2, 4, 5, 6, 9, 10] that a conspicuous place in the production of these changes belongs to a reflex component, particularly during the action of the muscles of both adequate (physical work, stretching of the muscles by a load) and inadequate (electric shock, vibration, heat, chemical agents) stimuli.

N. I. Kozin [3] observed in children a conditioned reflex rise in the blood pressure to a bell and to the word "bell," reinforced by physical exercise. In modern Soviet textbooks of physiology and in some reports of investigations [8, 11] changes in the arterial pressure during imaginary work and also in the periods before starting work or activity are treated as conditioned reflex in origin. However the properties of these conditioned reflexes have received inadequate study.

In this connection we made an attempt to investigate some of the properties of the conditioned reflexes formed on the basis of unconditioned changes in the arterial pressure during stimulation of proprioceptors.

EXPERIMENTAL METHOD

The experiments were carried out on 3 dogs – Trezor, Jack and Sharik. The arterial pressure was recorded in the common carotid artery exteriorized in a skin flap by means of L. N. Deriabin's apparatus. This apparatus is so constructed that a fall in the curve of the kymogram corresponds to an increase in the arterial pressure and vice versa, and only the maximum arterial pressure can be measured.

The stimulus for the proprioceptors was a static load equal in the size to 80% of the body weight of the animals. A bag containing sand was placed on the animal's back. The conditioned stimuli were a positive electro-metronome with a frequency of 150 strokes per minute (EM_{150}) and a differential electrometronome with a frequency of 75 strokes per minute (EM_{75}). Delayed conditioned reflexes were established. The delay amounted to 10-30 seconds. The unconditioned stimulus was applied to two of the dogs for 4 minutes and to one for 2 minutes, depending on the time over which the animals were able to support the load without movement. The reaction to the positive conditioned stimulus was recorded during periodical tests of its isolated application.

At the beginning of the investigation the orientational reflexes to the apparatus and to the conditioned stimuli were extinguished, and the character of the changes in the arterial pressure under the influence of the static load revealed. In addition, by repeated measurements of the arterial pressure we were satisfied that compression of the common carotid artery by the cuff did not in itself cause any variation in its level. In this respect we confirmed the findings of Wilhelmy and his co-workers [12] that the significant variations in the arterial pressure observed at the start of its systematic measurement, after the dog has become acclimatized to

the apparatus, become smoothed out and the arterial pressure becomes constant for a given animal, although it differs from one dog to another.

EXPERIMENTAL RESULTS

The results shown in the table demonstrate that in different dogs the conditioned reflexes which we studied appear roughly the same. The formation, restoration and reorganization of the conditioned reflexes take place rapidly; they are extinguished much more slowly.

Data on the Properties of the Conditioned Reflexes Formed in Dogs on the Basis of Unconditioned Reflex Changes in the Arterial Pressure Arising Under the Influence of a Static Load

Properties of the conditioned reflexes	Number of combinations (applications) of the stimuli to the dogs		
	Trezor	Jack	Sharik
Extinction of the reaction to compression of the carotid artery with the cuff	7	9	8
Extinction of the orientational reaction to the conditioned stimuli (EM_{150} and EM_{75})	4	5	3
Formation of a conditioned reflex to EM_{150}	3–7	4–10	2–8
Extinction of the conditioned reflex to EM_{150}	14–18	16–24	9–18
Restoration of the conditioned reflex to EM_{150}	1	1	2–6
Formation of differentiation to EM_{75}	2–4	7–11	4–5
Simultaneous transformation of the signal meaning of a pair of conditioned stimuli	5–7	4–7	5–8
Reverse transformation of the signal meaning of the pair of conditioned stimuli	4–5	3–5	4–6

At the start of formation of a conditioned reflex, a positive conditioned stimulus, applied in isolation, causes considerable variations in the level of the arterial pressure, particularly at the end and immediately after cessation of the action of the stimulus. Subsequently the changes in the level of the arterial pressure arising under the influence of the stimulus approximate those which are observed during the use of the static load (Fig. 1, a). At this period the conditioned stimulus – quite independently of whether it accompanies merely the start of the action of the unconditioned stimulus or the whole period of its action – when applied in isolation fully reproduces the action of the unconditioned stimulus. Later on, repeated combinations of the conditioned and unconditioned stimuli lead to a gradual diminution in the variations in the level of the arterial pressure. Next these stimuli may completely fail to evoke any changes in the arterial pressure. Under these circumstances a diminution in the variations and disappearance of changes in the arterial pressure are observed much sooner by use of the conditioned stimulus than by actual physical loading.

During extinction of the conditioned reflex, with a maximum reaction to EM_{150} at the start of nonreinforcement, considerable fluctuations in the level of the arterial pressure are also observed. Later on these fluctuations become diminished in association with a fall in the maximum arterial pressure, and the action of the conditioned stimulus leads to a fall in the level of the arterial pressure. If the conditioned stimulus is applied without reinforcement later on, then eventually it will cause no changes in the level of the arterial pressure exceeding the limits of the ordinary variations (see Fig. 1, b).

After extinction of the conditioned reflexes they were restored, and at the maximum of the changes in blood pressure differentiation to EM_{150} was developed. On its first application, the differential stimulus (EM_{75}) produces almost the same magnitude and direction of change in the arterial pressure as does EM_{150}. In subsequent tests of the influence of the nonreinforced EM_{75} the level of the arterial pressure falls and becomes lower than its variation observed when the stimuli are not in operation. At this period an obvious reaction is observed also to the unconditioned stimulus and to positive and inhibitory conditioned stimuli (Fig. 2).

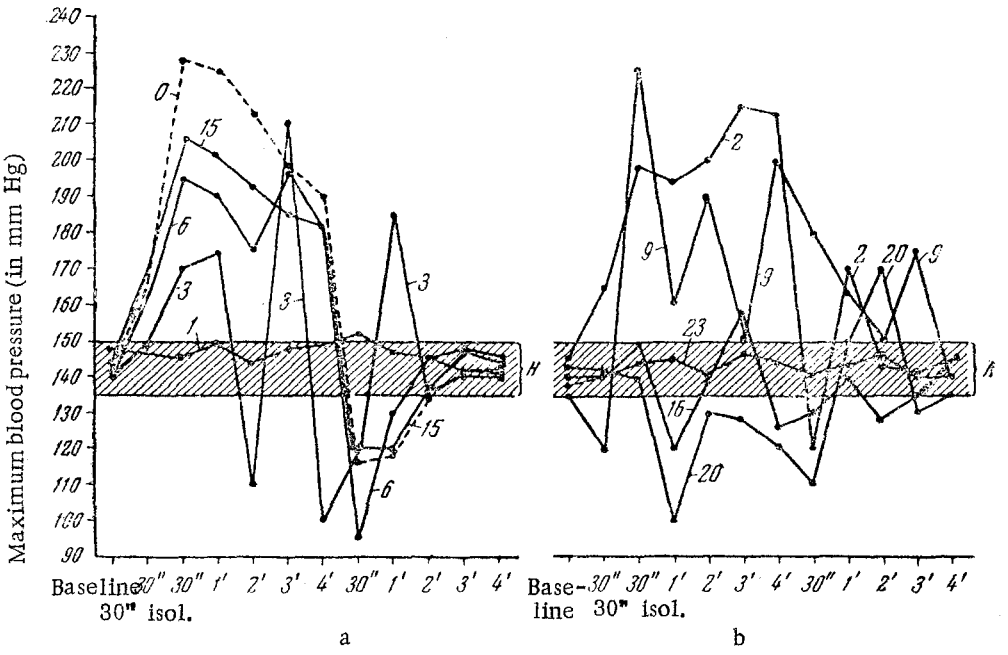

Fig. 1. Changes in the level of the arterial pressure in the dog Sharik. a) In the process of formation of the conditioned reflex; O) during the 15th combination of stimuli and during the action of EM_{150} in isolation after the 1st, 3rd, 6th and 15th combinations; b) in the process of extinction of the conditioned reflex during the 2nd, 9th, 16th, 20th and 23rd nonreinforcement; baseline – level of the initial blood pressure before this particular trial of the action of the stimulus; 30" isol. – action of the conditioned stimulus in isolation for 30 seconds; 30", 1', 2', 3', 4' – time of action of stimuli, and the later – 30", 1', 2', 3', 4' – time after their action; H) variations in the level of the blood pressure at times other than when the stimuli were applied.

Simultaneous transformation of the signal meaning of a pair of conditioned stimuli takes place rapidly. With the first combinations of the differential stimulus none of the changes in the level of the arterial pressure take place with the static load that are observed when the load is acting in isolation. The reaction to the unconditioned stimulus is inhibited by the existing differential stimulus. After 2-3 applications of these stimuli the level of the arterial pressure is increased considerably more under their combined influence than by the action of physical load alone. After 7-8 applications the changes in the arterial pressure become the same as those which took place earlier under the influence of the combination of stimuli for the consolidated conditioned reflex. Reverse transformation of the conditioned reflexes takes place rather more rapidly than the primary transformation.

We carried out "conflict" experiments on the dog Sharik. As a preliminary we applied EM_{150} and EM_{75} for 4 minutes. The reaction to these stimuli was the same as that shown in Fig. 2. For a period of 2 days we made 5 applications for 2 minutes of the positive conditioned stimulus, and immediately after these, also for 2 minutes, the inhibitory conditioned stimulus. During the first three of these actions (on the 1st day) the conditioned stimuli, during their time of action, caused changes in the arterial pressure in accordance with their signal meaning. During the subsequent two "conflicts" (2nd day) the reaction to the positive conditioned stimulus diminished but the differential stimulus caused an increase in the level of the arterial pressure. On

the 3rd and 4th day after the "conflict" the level of the arterial pressure at times when no stimuli were being applied was from 10-20 mm of mercury above normal. Usually in our experiments the level of the blood pressure fell to its initial value from 3-4 minutes after the action of the stimuli. Starting with the first conflict between the excitatory and inhibitory processes in the cerebral cortex, the level of the arterial pressure increased by a high degree and returned to its original value only after 13-15 minutes. Under the influence of a combination of the conditioned stimulus with the unconditioned, the blood pressure also rose much more than usually, and the initial level was restored after 9-11 minutes. Further observations on the changes in the level of the blood pressure under the influence of conditioned stimuli revealed, usually in the form of a neurosis, inhibitory, ultraparadoxical and equalizing phases. The reactions of the animal both to signal stimuli connected with kinesthesia and to unconditioned proprioceptive stimuli became inadequate. The animal reacted to the conditioned stimuli in accordance with their signal meaning only 10 days after the "conflict."

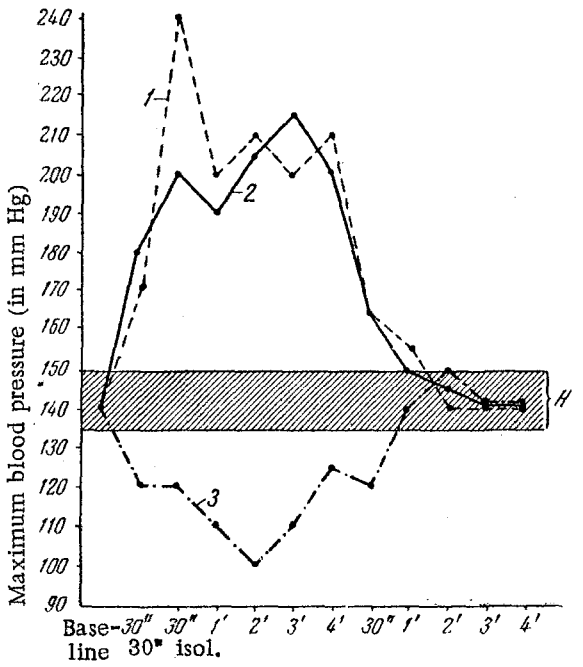

Fig. 2. Changes in the level of the blood pressure after reinforcement of conditioned reflexes in the dog Sharik. 1) during reinforcement of the conditioned stimulus by a static load; 2) during action of the positive conditioned stimulus in isolation; 3) under the influence of the differential stimulus. Symbols as in Fig. 1.

The results of the experiments which were carried out confirm the correctness of the assertion of M. R. Mogendovich, based on insufficient factual material, that "vegetative functions are subordinated to the locomotor functions during the predominant role of the higher nervous activity" ([6], p. 18). Nevertheless it is difficult to agree with this author that in the conditioned reflex reaction of the cardiovascular system to muscular work "the main part is played by the unconditioned reflex mechanism of regulation" [[6], p. 259]. M. R. Mogendovich bases this conclusion on the fact that in man a verbal signal evokes a smaller acceleration of the heart rate than does muscular exercise. In our own experiments, at the beginning of consolidation of the conditioned reflexes the conditioned stimulus caused almost the same changes in the level of the arterial blood pressure as the unconditioned. Only later on, after repeated applications of combinations of the conditioned stimulus with the unconditioned, did the reaction to the first of these develop significantly more rapidly than to the second, diminish and even disappear. In our opinion this is not evidence in favor of the predominance of the unconditioned reflex regulation of the cardiovascular system over the conditioned reflex regulation.

The results of our experiments demonstrate that the conditioned reflexes formed on a basis of unconditioned reflex changes formed on a basis of unconditioned reflex changes in the arterial pressure during stimulation of proprioceptors are of great importance in the life of the animal; it may be suggested that they are mainly responsible for bringing about rapid adaptation of the function of the cardiovascular system to the constantly changing conditions of the external environment of the animal.

SUMMARY

The conditioned reflexes formed on the basis of unconditioned changes of the blood pressure in stimulation of the proprioceptors with the aid of static load were studied in experiments on 3 dogs. It was demonstrated that the reflexes referred to above are rapidly acquired, reestablished and changed, but in comparison with this their extinction is slower. It is thus assumed that these conditioned reflexes provide the adjustment of the function of the cardiovascular system to the constantly changing conditions of the body existence.

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*In Russian.