TIME AND CONDITIONS OF PERFORMANCE OF MUSCULAR WORK AS FACTORS OF ORGANIZATION OF DIURNAL PERIODICITY

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(Received April 10, 1957. Presented by Academician K.M. Bykov)

The study of the individual components of daily activity and of their effect in forming the diurnal stereotype of physiological functions, in particular of motor function, is of considerable importance in the physiology of labor and sport.

A large number of papers have been devoted to the study of the diurnal periodicity of motor activity, in relation to nutrition, illumination, temperature, and other factors [1, 2, 3, 4, 6, 8, 9, 12, 14, 15, 16, 18, 19, 20, 21, 22, 23, and many others]. Relatively few papers [5, 7, 10, 11, 13, 17] have dealt with the formation of the diurnal rhythm of motor activity, in connection with muscular activity. But this subject is of particular importance to the study of the physiology of work and of physical training.

In the present paper we have attempted to answer the question of whether the time at which work is performed, and the environmental conditions in which it takes place, are factors affecting formation of diurnal periodicity. We applied the conditioned reflex method to the study of this problem.

EXPERIMENTAL METHOD

Our experiments were performed on long-eared hedgehogs, which under natural conditions display a pronounced diurnal rhythm of physiological function. We examined their motor activities, which were recorded by means of an actograph. The animals were placed in a cage, connected through a corrugated tube with a pressure capsule (tambour). The lever of the tambour was in contact with the surface of a drum, which rotated once in 24 hours. In this way, we recorded any oscillations of the cage due to the movements of the animal.

When under observation, the animals were placed in cages situated in a room in which temperature and illumination were kept constant. Each animal regularly performed a given amount of work (running in a treadmill), at a fixed time of day, and was only removed from its cage for this time. Having become habituated to this routine, the animals needed no inducement to enter the wheel. The mere presence of the wheel acted as a stimulus to active running.

The animals were fed once daily (always at the same time), and were always given the same food. An interval of several hours intervened between feeding and experimental physical work (work was performed in the mornings, feeding in the evenings).

EXPERIMENTAL RESULTS

A. Formation, Within the Diurnal Stereotype, of Conditioned Reflexes to the Time and Place of Performance of Physical Work

Our experiments showed that regular performance of physical work at a fixed time of day caused changes in the diurnal rhythm of motor activity exhibited by the animals at the beginning of the experiment. Thus, we

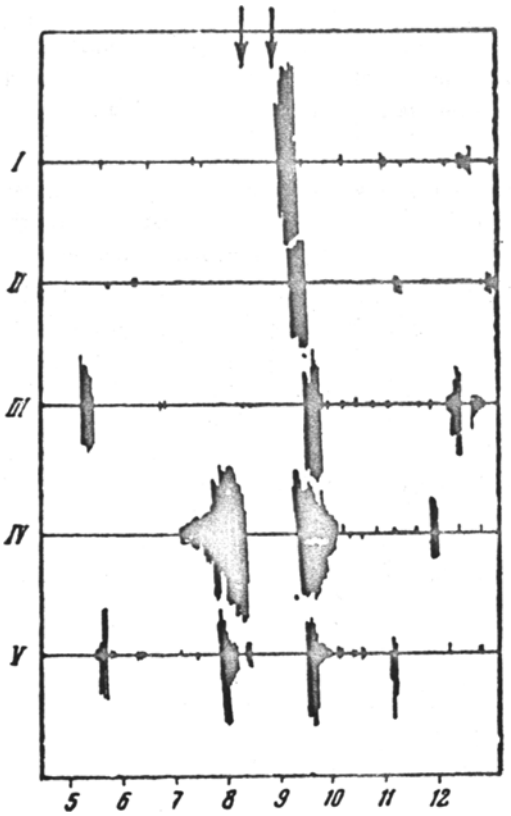

Fig. 1. Formation of a conditioned reflex to the time of performance of physical work (Hedgehog No. 1). Tracings of motor activity. The arrows show the time of placing the animal in the wheel, and of its removal from it: I) experiment of October 26, 1950; II) October 27, 1950; III) October 28, 1950; IV) October 30, 1950; V) October 31, 1950. Below: time of day.

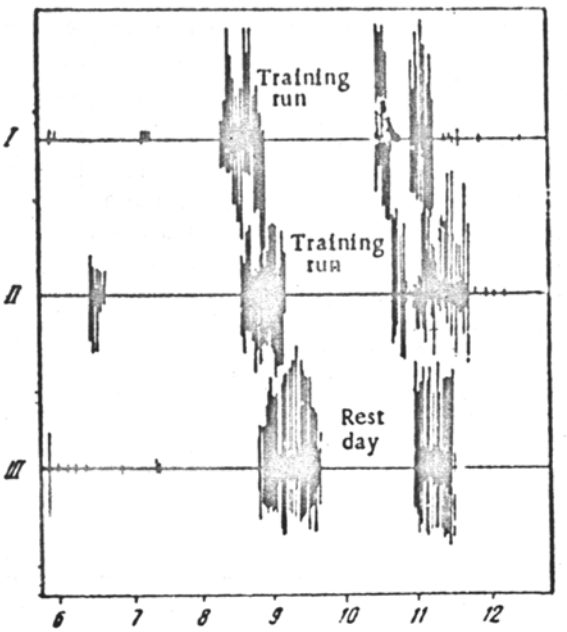

Fig. 2. Conditioned reflex motor activity elaborated in response to physical work (Hedgehog No. 3): I) training day; experiment of October 20, 1950; II) training day; experiment of October 21, 1950; III) rest day; October 22, 1950. Below: time of day.

noticed that after being exercised in the wheel they continued to run backwards and forwards in their cages for a certain time (Figure 1: I, II, III). With continued repetition of their daily training runs, phases of motor activity began to appear in the diurnal cycle, preceding their transfer to the wheel (Figure 1: IV, Figure 2: I, II); these were of the nature of a conditioned reflex to the time of performance of physical work, at a fixed hour of the day.

Once these two phases of activity had been formed within the diurnal stereotype – one preceding, and the other following, the training run – they could be observed not only on days in which such runs took place, but also on days of rest (Figure 2: III, and Figure 3: I, II), which is evidence of stabilization of the experimental diurnal stereotype. Thus, new phases of "spontaneous" motor activity had appeared in the diurnal cycle as a result of regular performance of physical work at a fixed time of day.

It is evident, however, from the recordings, that motor activity was not seen during the period which corresponded with that of the routine training run. But if the animals were taken out of the cages at this time, and raised to the wheel, they jumped in, and began to run. It follows that the motor excitation observed while the animals are in the wheel may be considered to be a conditioned reflex to the environmental conditions. When the animals were left in their cages this reflex was inhibited, owing to the absence of conditions adequate for muscular exertion.

B. Extinction of Conditioned Reflexes to the Time and Place of Performance of Physical Work

A reconstruction of the stabilized diurnal stereotype was effected, with the object of extinguishing the experimentally formed reflexes to the time and place of performance of physical work. For this purpose we discon-

tinued the training runs, and shifted the feeding time to another time of day. All the other experimental conditions remained unchanged.

Figure 3 shows the actograms recorded before reconstruction of the stabilized stereotype, and while this was in progress. The two upper actograms (I and II) show clearly the phases of motor activity related to the time of performance of physical work and appearing at about 9 a.m., before the regular exercise period, and at 10:30-11 a.m., after this period.

On the second day of conversion (Figure 3: III), when the feeding time was moved from 6 p.m. to 12 noon, the conditioned reflex activity usually seen at 9 a.m., in connection with the training run, persisted, although at a slightly different time. On the following day this conditioned reflex activity was absent, but on the same day we observed the appearance of a new conditioned reflex, expressed as motor activity seen between 11 and 12 a.m., i.e., at a time connected with the new feeding schedule of the animals (Figure 3: IV).

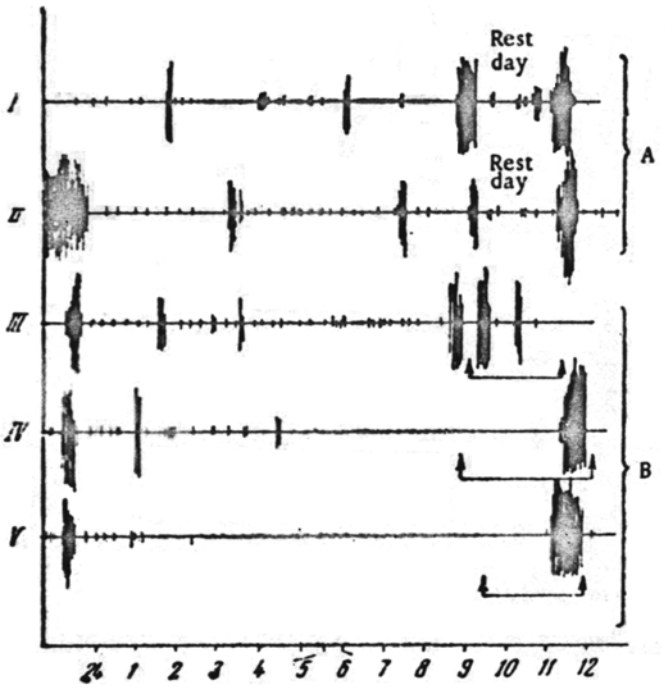

Fig. 3. Extinction of a conditioned reflex to time of performance of physical work, during the process of conversion of a diurnal stereotype (Hedgehog No. 2): A – before conversion of the diurnal stereotype: I) 21st day after beginning of training at a fixed time of day (October 15, 1950); II) 24th day after beginning of training at a fixed time of day (October 18, 1950). B) After conversion of the diurnal stereotype: III) first day of extinguishing the reflex (October 19, 1950); IV) second day of extinguishing the reflex (October 20, 1950); V) third day of extinguishing the reflex (October 21, 1950). Below: time of day.

Discontinuation of the training runs was associated with change in the signal significance of environmental stimuli which coincided with this activity. Thus, during the experiments, signal significance was acquired by sounds connected with the entry into the room of the experimenter (footsteps, opening of the door), and with the noise made by the rotating wheel. The entry of the experimenter into the room, however quietly this was effected, invariably gave rise to increased motor activity of the hedgehogs. It should be noted that the effect of the morning visit of the experimenter was always reinforced by the training run, and of the evening visit by provision of

food. Thus, the experimenter fulfilled the role of a positive stimulating signal, releasing motor activity in the animal. This was very clearly shown on occasions when the animals had contrived to open the cages, from which they escaped, and hid themselves under any available cover in the corners of the room. As soon as the experimenter entered the room, however, they at once abandoned their cover and ran towards him. This behavior was the rule before conversion of the diurnal stereotype. From the moment this was achieved, the signal significance of auditory stimuli connected with the entry of the experimenter underwent change. The evening visit was no longer associated with provision of food. Training runs no longer followed the morning visits of the experimenter.

The motor activity response of the animals to the presence of the experimenter changed accordingly. It is evident from Figure 3 (III) that on the first day of the changed schedule the arrival of the experimenter in the morning, at the time at which the training run used to take place, was associated with the appearance of motor activity. However, on this day the conditioned reflex formed to the time of the training runs was not reinforced by a run in the wheel. On the following day (Figure 3: IV) extinction of the conditioned reflex was seen. The animal evinced no motor activity in response to the entry of the experimenter. The same applied to the next day (Figure 3: V), although the wheel was turned within the room. The cessation of motor activity was found to have taken place some hours before the morning visit of the experimenter.

As feeding time approached (at 12 noon on the new schedule, instead of at 6 p.m. as previously), the animal, which had until then been immobile, got up and moved rapidly around the cage.

Hence, the absence of motor activity, at those times of the day which, before conversion of the stereotype, corresponded with periods of conditioned reflex excitation connected with impending exercise, is evidence of the presence of an active conditioned reflex inhibitory process in the motor analysor.

Thus, the absence of physical exercise which had been performed by the animals at a fixed time (training) converts this time into a negative signal stimulus. In place of excitation, manifested as motor activity of the animals at times corresponding with the former training schedule, conditioned reflex inhibition now supervenes. External stimuli whose incidence coincided with these times now also acquire the significance of negative signals. It is of special interest that the influence of the inhibitory process developing in the diurnal stereotype on extinction of the conditioned reflex to time of performance of physical work was now also apparent during the period preceding that of former excitation. Concentration of inhibition was only achieved on the fourth day of conversion of the diurnal stereotype. Inhibition then applied only to the time of motor activity related, before extinction, to the training run.

Our findings permit the following conclusions.

Stimulation by means of signals of motor activity of an animal is an important factor, determining the organization of any motor activity in time. The time of performance of physical work, and the environment in which it is performed, are components of the process of formation of the diurnal rhythm of motor activity, since they represent signals evoking excitation or inhibition of the motor analysor. The positive conditioned reflexes to time and place of performance of physical work are thus to be included among the causes of apparently "spontaneous" motor activity.

SUMMARY

The investigations established that the time of accomplishment of muscular work and the environmental conditions in which it is performed are the factors which organize the 24-hour periodicity of motor activity. This is due to the fact that both the time factor and the environmental conditions are the signals for the appearance of excitation and inhibition in the motor analysor. Formation of positive conditioned reflexes to time and environment in which the muscular work is performed is one cause of the occurrence of the so-called "spontaneous" motor activity.

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