POTENTIATION OF THE CHRONOTROPIC REACTION OF THE RABBIT HEART DURING NOCICEPTIVE STIMULATION

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UDC 612.173.3:615.851.1

KEY WORDS: heart; chronotropic reaction; heart beat.

Recent studies of the ability of man and animals to control their heart rate (HR) by biofeedback have made it necessary to describe the fundamental processes and mechanisms on which it is based [1, 2, 8, 10]. On the analytical plane it is important, in particular, to distinguish the specific processes connected with the effect of feedback stimulation, and learning (memory trace) as a result of association between changes in functional state and reinforcement, and of nonspecific processes such as habituation and extinction of the orienting reaction, which have been described previously within the framework of the classical model of learning [4, 5, 7]. The question of manifestation of the effect of facilitation and potentiation of autonomic responses during regular or irregular stimulation has not been adequately studied [3, 9].

The aim of this investigation was to determine the basic characteristics of potentiation of the chronotropic reaction of the rabbit heart revealed during prolonged nociceptive stimulation with a frequency of 0.05-2 Hz. This frequency range is very close to the stimulation pattern arising in different stages of biofeedback control [6].

EXPERIMENTAL METHOD

Twelve experiments were carried out on rabbits weighing 2.5-3 kg, curarized with gallamine, and maintained on artificial respiration for 3-8 h (UIDZh-1 apparatus, respiration rate 25-30 cycles/min). The animal's temperature was maintained at the assigned level (38-39°C) with an accuracy of 0.2°C. The cardiointervalogram (ECG recorded with leads from the forelimb and hind limb) and stimulus markers were recorded on the N-338 ink-writer and Tembr-2 tape recorder. Integrated values of HR or duration of the RR interval obtained by the MN-7M analog computer over periods of 2.5 or 10 sec were displayed by a digital printer. Cardiointervalograms were interpreted by the NTA1024 analyzer. For electrodermal stimulation pulses from an ÉSU-2 stimulator were passed through needle electrodes to the hind limb, with the following parameters: pulse duration 1-3 msec, 1-9 pulses per volley, volley duration 10-50 msec, strength of current between 0.5 and 2 mA. The initial background activity, the period of stimulation, and the background after the end of stimulation were recorded for 3-10 min (the experiment consisted of 25-60 periods). Changes in HR (cardiointervalogram) evoked by stimulation were assessed on the basis of the amplitude and shape of the response and the time for it to reach a maximum. Statistical analysis of the data was carried out on the NTA1024 analyzer and WANG 2200B computer.

EXPERIMENTAL RESULTS

It was shown previously [6] that the basic reaction of the rabbit HR to single electrodermal stimulation consists of two phases: an initial short and slight increase in HR, giving way to a powerful and prolonged reaction of slowing. During repetitive regular and also irregular stimulation a gradual increase in the magnitude of the reaction was observed in the course of stimulation up to a maximum: the effect of potentiation of the HR slowing reaction. The rate at which maximal potentiation was reached was determined by a certain constant effect cumulation time, between 16 and 60 sec (with extreme values of 12 and 270 sec), and was de-

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Laboratory of Physiology of Higher Nervous Activity, I. P. Pavlov Institute of Physiology, Academy of Sciences of the USSR, Leningrad. (Presented by Academician of the Academy of Medical Sciences of the USSR A. V. Smol'yannikov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 93, No. 6, pp. 18-21, June, 1982. Original article submitted June 10, 1981.

0007-4888/82/9306-0713$07.50

TABLE 1. Development of Maximal Potentiation of Slowing of HR during Repetitive Stimulation with Different Frequencies

Frequency of stimulation	Response to first stimulus, percent	Maximal response	
		time of response, sec	magnitude of response, percent
Once every 6 sec	101	32 (29—41)	156
Once every 3.5 sec	101	28 (19—33)	154
Once every 2 sec	102	26 (20—31)	156
Once per second	101	23 (16—27)	169
Twice per second	103	22 (15—29)	173

Legend. Limits of variations shown in parentheses.

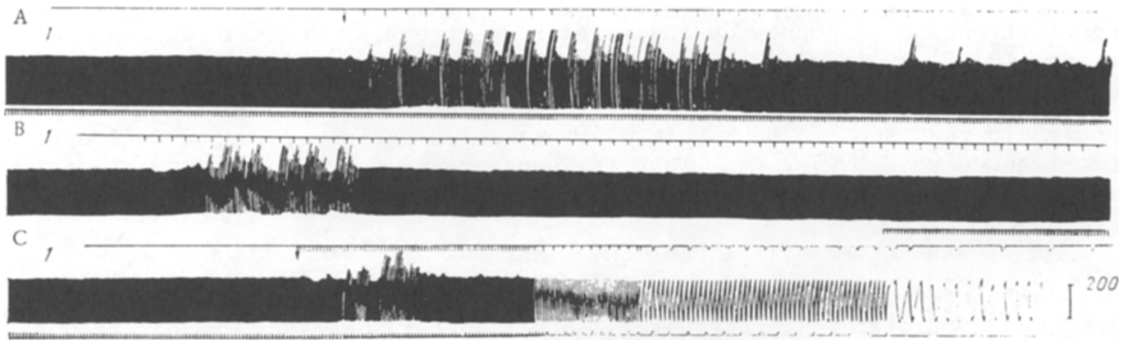

Fig. 1. Time course of rabbit HR during regular nociceptive stimulation at frequencies of once every 6 sec (A), once every 3.5 sec (B), and once per second (C). Parameters of stimulation: 14-16 V, pulse duration 1 msec, 5 pulses, duration of volley 15 msec. In each fragment: 1) initial background, 2) period of stimulation; from top to bottom: marker of stimuli, cardiointervalogram (mean RR interval 277 sec), time marker 1 sec (recording in fragment C at both slow and fast speeds).

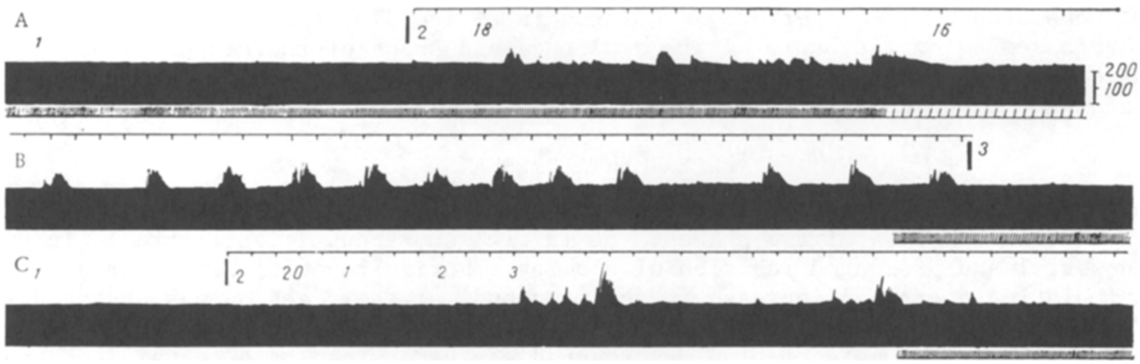

Fig. 2. Time course of HR potentiation reaction during infrequent regular stimulation (once every 13 sec) of varied intensity. A) Development of potentiation at beginning of first stimulation period in tests of 12, 20, and 16 V (one pulse); B) rhythmic potentiation effect developed at end of period (interval between fragments A and B is 200 sec); C) development of potentiation during 5th stimulation period during tests of increasing intensity (16 V, 1 pulse; 20 V, 1 pulse; 20 V, 2 pulses; 20 V, 3 pulses). 1) Initial background (mean RR interval 212 msec), 2) period of stimulation, 3) after end of stimulation. Remainder of legend the same as to Fig. 1.

termined as the optimal ratio between the frequency of stimulation and its intensity relative to the pain threshold for evoking the basic reaction of the rabbits.

By using the regular stimulation with an interval of 0.5-7 sec the time course of the potentiation effect could be demonstrated as a function of the parameters of frequency and intensity. Fragments of one experiment with stimulation once every 6 sec, once every 3.5 sec, and once per second for a period of 3-4 min are illustrated in Fig. 1. During stimulation once every 6 sec the response rose to its maximal value at the 7th-8th stimulus, i.e., after 35-40 sec. During the rise of the response and on the plateau, correlation was recorded between the frequency pattern of the response and the frequency of stimulation. After 115 sec of stimulation there was a marked decrease in the response, disturbance of rhythm binding, and slow extinction of the response. When the interval of stimulation was 3.5 sec the potentiation effect developed after 21 sec (7 stimuli), it lasted 35-40 sec, and disappeared completely in the subsequent tests (without a fluctuating course). The rhythmic pattern of the response was sufficiently well defined during the rise of the response and maximal potentiation. A more marked phase of initial quickening of HR was recorded to the first two stimuli.

During repetitive stimulation once per second the potentiation effect was observed after 20 sec and the plateau lasted 7 sec, after which the reaction was swiftly and completely extinguished; no correlation was found between the evoked response and the stimulation pattern. At the beginning of the period there was a marked phase of quickening of HR.

Potentiation effects at five different frequencies, obtained as a result of evaluations of 3-5 repeated series of regular stimulation in this experiment, are summarized in Table 1.

The time course of the HR potentiation reaction was much more complex during stimulation at a lower frequency and of moderate intensity (Fig. 2, interval 13 sec). The potentiation effect developed slowly over a period of many tens of seconds (Fig. 2A, B), the maximum of potentiation was reached after 250 sec, and the response pattern was rhythmic — to every 4th stimulus; the magnitude of the response was 126-134% of the background level. Development of potentiation during the 5th period of repeated stimulation during an increase in stimulus intensity, which developed after 50 sec and gradually died away with fluctuations in the course of 200 sec, is illustrated in Fig. 2C; in this case the rhythmic response pattern was not found.

The phenomenon of HR potentiation described above during infrequent repetitive nociceptive stimulation of moderate intensity gives rise to a considerable and long-lasting effect during prolonged repetition and it may have an appreciable effect on the end result of learning both with the classical and instrumental reflex procedures and also during biofeedback control.

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