THE CARDIAC COMPONENT OF CONDITIONED DEFENSIVE REFLEXES IN DOGS

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Cardiovascular conditioned reflexes in man and animals have been investigated in two different ways.

Some investigators [4] have studied the formation of conditioned cardiac and vascular reflexes in response to different extro- and interoceptor stimuli, while others [2, 3, 5] have studied the cardiovascular system and its participation in various complex conditioned reactions involving defensive movements, feeding, etc. In this way it has been shown that cardiovascular changes accompany any complex conditioned reflex act.

All positive conditioned feeding and motor responses are associated with an increased heart rate, and when the responses are inhibited, the heart rate is slowed. Nevertheless, at the present time a large number of problems concerning the structure of conditioned reflexes and their interrelationships remain unsolved. For instance it is not known to what extent the autonomic system is involved in the different features of conditioned reflex activity such as strength relationships, differential inhibition, disinhibition, and positive and negative induction.

We have made a study of heart-rate changes in positive and inhibitory motor responses to electrical stimulation.

METHODS

The experiments were carried out on four male dogs weighing 14-20 kg in whom a set pattern (stereotype) of defensive reflex movements had been established. The conditioned stimuli used were a bell of moderate strength, a 96 w lamp, a buzzer, a metronome at 120 beats per min for the positive, and another at 60 beats per min for the inhibitory signal. The signals were applied for ten seconds; threshold electrical stimulation (50 c/s 0.8-1 mA) was applied during the seventh second. During the application of the conditioned and unconditioned stimuli, and also during the period between them, records were made of the motor response, respiration, and electrocardiogram (using an ink writing electrocardiograph). The R-R intervals were measured from the ECG, and plotted graphically to show the variation in heart rate.

RESULTS

The animals represented different types of higher nervous activity. It was possible to observe the relationship between the motor responses and changes in heart rate for the different types. Dogs which judged by general excitability and the strength of the excitatory and inhibitory processes were of the two extreme types, showed reactions as follows:

In Blanche, who belonged to the weak inhibited type, the heart rate was slower than in the others and had a well-marked sinus (respiratory arrhythmia). While the animal was in the experimental chamber, before the beginning of the experiment the R - R interval lay between 0.54 and 0.84 sec. In Tarzan who was of the excitable ("unrestrained") type, the heart rate was rapid, and there was no sinus arrhythmia. The R - R interval had an average value of 0.32 sec. In Storm, excitation predominated, while in Rusty it was relatively weak, and these two dogs were therefore of an intermediate type. In Storm, before the experiment, the R - R interval varied from day to day from 0.42-0.44 to 0.46-0.50 sec, while in Rusty the variation was from 0.42-0.46 to 0.72-0.98 sec.

In all the dogs, after applying positively conditioned signals the R - R interval decreased, and in Storm and Rusty the sinus arrhythmia disappeared. In Blanche, the positively conditioned signals had only a mild accelerating action on the heart. For instance, in Storm and Rusty the R - R interval was reduced from 0.42-0.44 to 0.30 and from 0.42-0.46 to 0.32 sec respectively in response to the sound of a bell, while in Blanche, the same stimulus reduced the interval from 0.54-0.84 to 0.50-0.82 sec.

In each dog, the accelerating action of the positively conditioned signals was shown to a different extent, depending on the strength of the stimulus. The greatest effect, which was accompanied by enhanced respiration, was produced by the bell and the buzzer, while the least response was produced by light. The results showed that the ranking sequence of the stimuli was the same for the cardiac as for the motor and respiratory responses. For example, in Storm (experiment of June 20, 1958). the bell caused the R - R interval to fall from 0.46-0.50 to 0.30 sec, while the light stimulus reduced it from 0.50-0.54 to 0.38 sec.

It should be noted that in Tarzan in whom the heart rate was high before the experiment, the effect on the heart rate was less. Reinforcing the positive conditioned reflex as a rule further increased the rate.

The results of the effect on heart rate of inhibitory (differentiated) stimuli were particularly interesting. In Storm, Blanche, and Rusty, the inhibitory signal slowed the heart, and the effect was greater when differentiation of the motor response was complete. For instance, in Rusty (experiment June 20, 1958), the inhibitory metronom signal changed the R - R interval from 0.32-0.34 to 0.52 sec.

In Tarzan, in whom the differentiation had been elaborated with great difficulty and was very unstable, the inhibitory metronome signal of 60 beats per second, which had become completely differentiated with respect to the effect on the motor response (though it caused a marked inspiration), the heart rate was increased. It was interesting that in the remaining three dogs, as soon as the inhibitory signal was removed, the heart rate increased, whereas in Tarzan it was slowed.

The effect of conditioned defensive reactions was also studied in dogs in whom conditions reflex activity was disturbed.

It is well known that one of the commonest manifestations of conditioned reflex disorder is a disturbance of the quantitative relationships between stimulus and response. It was found that this relationship was also disturbed in so far as the heart reat was concerned.

In Rusty (experiment on July 1, 1958) after injecting 0.03 mg/kg of proserin, there was a phasic response, and a paradoxical motor reaction. The heart rate was similarly affected. Instead of the expectedly greater increase in response to the bell than to the light, the greater increment in rate was caused by the light, when the R - R interval fell from 0.54-0.60 to 0.36 sec, while when the bell was applied the interval was reduced only from 0.52-0.54 to 0.40 sec. The normal stimulus-response relation ships were maintained for respiration (Fig. 1AB).

As has been shown above, in all the dogs positively conditioned signals caused an increase in heart rate corresponding to the motor and respiratory responses to the conditioned signal. However, in Storm the conditioned response to the bell was reversed (experiment of July 8, 1958). As a rule, while the animal was in the chamber before the beginning of the experiment and before the first bell-signal had been presented, it was very restless and breathing and heart beats were rapid. When the animal was in this condition, sounding the bell caused an increased inspiration and a gradual reduction of the motor response and, more important still, the slowing of the pulse (the R - R interval increased from 0.28 to 0.48 sec); there was thus a paradaxical relationship between the cardiac response and the signal given (Fig. 1C). When the bell signal was given three minutes later, it caused a tachycardia, the R - R interval being reduced from 0.28 to 0.24 sec.

The experiment performed on Storm on June 19, 1958 will serve as an example of a case where there was a different cardiac response to the conditioned signal and

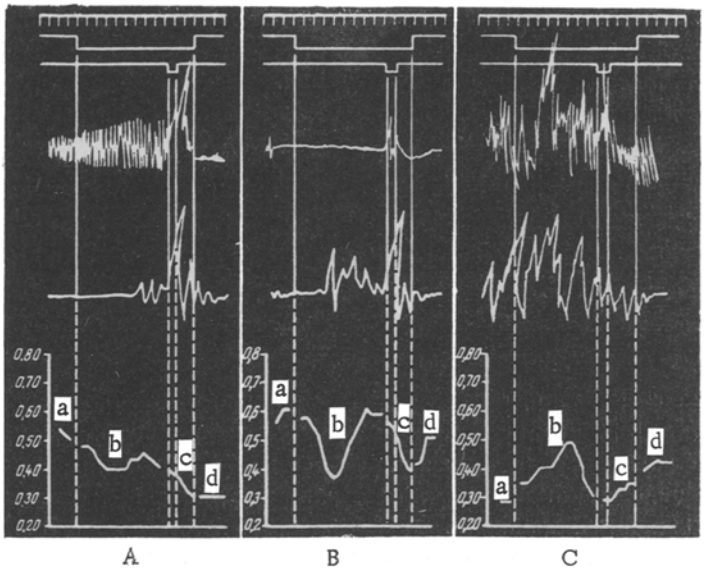

Fig. 1. Changes in heart rate when the normal stimulus-response relationship was disturbed. A) In response to bell; B) in response to light (Rusty - experiment of July 1, 1958); C) in response to bell (Rusty - experiment of July 8, 1958). a) Before presenting the conditioned signal; b) during seven seconds application of the conditioned signal alone; c) after reinforcement with electrical stimulus; d) after the cessation of the conditioned stimulus. Curves, from above downwards: Time marker (4 sec); conditioned reflex marker; unconditioned stimulus (electrical) marker; respiration trace; motor response; graph showing changes in heart rate (R -R interval).

where there was also failure (inhibition) of the motor response, and a weakened respiratory reaction to a light stimulus. These changes were associated with a marked shortening of the R - R interval from 0.5 to 0.38 sec.

Because any conditioned reflex (in this instance the defensive reflex) is made up of somatic and autonomic components it gives a considerable amount of information on the functional condition of the subcortical autonomic centers; we therefore carried out a set of experiments designed to determine the relationship between change in heart rate and the condition of adrenergic mechanisms of the adrenergic autonomic ganglia.

For this purpose an injection of 1 mg/ kg aminasin was given 15-20 min before the experiment. The effect was to suppress the motor conditioned response and to inhibit respiration.

During the period of application of the positive conditioned signals, the heart rate changed characteristically. In all the dogs, aminasin reduced it. Although the conditioned positive signals then produced little or no motor response, they did reduce the bradycardia caused by the aminasin injection; when the conditioned signals ceased, the heart rate was once more reduced (Fig. 2A, B). When the motor and respiratory responses were not completely eliminated, the reduction of the bradycardia was better shown (Fig. 2B).

Applying the inhibitory metronome signal of 60 beats per sec after giving aminasin further increased the bradycardia caused by the drug. When the inhibitory stimulus ceased, the heart rate again increased (Fig. 2C). The extent of the change in heart rate differed in the different dogs.

In Blanche who had a slower pulse and a stronger sinus arrhythmia than the other dogs, the inhibitory metronome signal of 60 beats per min increased the R - R interval from 0.50 - 1.44 to 0.50-1.72 sec. But in Tarzan, in whom aminasin caused but little reduction in heart rate, the reduction caused by the inhibitory metronome signal fell much less, the R - R interval increasing only from 0.46-1.0 to 0.46-1.14 sec.

It can be seen therefore that the effect of conditioned stimuli of different strengths and significance will produce consistent changes in the heart rate, and that their degree and nature will depend to a large extent on the type of nervous system possessed by the animal and on its general level of excitability.

It has been shown that the normal stimulus-response relationships and the nature and the stability of the differentiation of the motor response have their counterpart in heart rate changes. On the other hand, in cases of disturbance to the higher nervous centers, there was a failure of correspondence between heart rate changes and the strength and significance of the conditioned stimuli, and the responses of the different components of the conditioned reflexes were not consistent.

It was also shown that when the motor and respiratory components were inhibited by blocking the adrenergic mechanisms of the reticular formation by giving aminasin [1], the condition signals were still effective in producing heart rate changes, and also retained their signalling significance, so that after aminasin bradycardia, positive conditioned signals increased the heart rate, and negative reduced it.

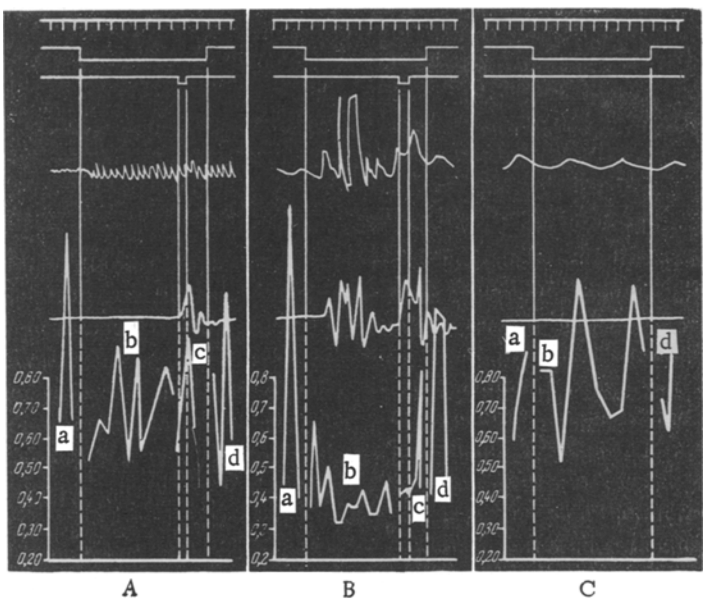

Fig. 2. Changes in the heart rate caused by positive and inhibitory signals applied after injecting aminasin. A) In response to bell; B) in response to buzzer (Storm, experiment of June 21, 1958); C) in response to metronome at 60 beats per sec (Rusty, experiment of June 21, 1958). Indications as in Fig. 1.

The results show that a study of the autonomic and somatic components of conditioned reflexes and their interaction, besides being of physiological interest are also of importance in connection with many pharmacological investigations.

An animal in which a defensive conditioned reflex having well-shown autonomic and somatic components has been elaborated is an extremely convenient model for the study of various substances affecting the central nervous connections, and the peripheral effects of central (cortical) excitation.

SUMMARY

A study was made of the cardiac component of conditioned positive and inhibitory reflexes. Experiments were performed on four dogs in which a set of conditioned reflexes had been developed.

Changes in heart rate occurring during the presentation the conditioned signals were largely determined by the type of nervous system and by the general degree of excitation. The signalling significance of the conditioned stimuli, the strength-stimulus relationship, and the nature and stability of the differentiation of the cardiac response were consistent with the motor conditioned reflex.

Finally, it was shown that when the motor are respiratory responses were inhibited by 1 mg/ kg aminasin, the conditioned signals were not only effective in causing heart-rate changes but also retained their signalling significance: when applied during aminasin bradycardia, positive signals increased and inhibitory decreased the heart rate.

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