A QUANTITATIVE EXPERIMENTAL INVESTIGATION OF THE VESTIBULO-AUTONOMIC REFLEXES

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UDC 612.833.886-08

Despite many investigations of the vestibulo-autonomic reflexes, only a very few have considered the relationship between the accurately measured intensity of an adequate stimulus to the vestibular analyzer and the autonomic response reaction [2,5-7,9-11]. In particular, the question of the threshold levels of adequate vestibular stimuli evloking autonomic reactions has not yet been solved. Evidently, the lack of information on this problem is due to the absence of suitable experimental techniques.

The object of the present investigation was to determine the threshold values of an adequate stimulus applied to the semicircular canals causing an autonomic reaction in rabbits, and also to study the qualitative relationship between the magnitude of the angular acceleration and the autonomic response reaction.

EXPERIMENTAL METHOD

Apparatuses of the VU-2 and VU-3 types were used in the investigation, capable of providing a wide range of angular accelerations and velocities [1]. The rabbit, fixed in a frame, was rotated at a subthreshold angular acceleration of 5 deg/sec^2 up to a constant angular velocity of 5-180 deg/sec. After a period of rotation at uniform velocity for 2 min, the stop-stimulus was given. The braking time was 0.15 sec, corresponding to a negative angular velocity of between 33 and 1200 deg/sec^2.

Before rotation, during rotation at uniform velocity, and for 30-90 sec after the stop-stimulus, the pulse rate, the frequency and amplitude of the respiratory movements, and the maximal arterial pressure were recorded separately every 10 sec. In some animals, the pressure was measured in the carotid artery exteriorized in a skin flap, while in others it was measured in the brachial artery by means of a piezoelectric detector [3]. The interval between two successive rotations was 2.0-2.5 min. The intervals between repeated investigation of the same animal were 1-3 days. The magnitude of the reflexes was judged by the difference between the indices before and after rotation. Statistical analysis of the results was by Student's method.

Altogether, 252 experiments were carried out on 101 animals, including 27 experiments on 9 labyrinthectomized rabbits (labyrinthectomy was performed by an operative method).

EXPERIMENTAL RESULTS AND DISCUSSION

Immediately after the stop-stimulus, a visible change took place in the amplitude and frequency of the animals' respiratory movements and changes were also found in the arterial pressure. In the overwhelming majority of cases, the changes in respiration consisted of a decrease in amplitude and a simultaneous increase in frequency of the respiratory movements. The amplitude began to change when the angular acceleration was 66 deg/sec^2. With a further increase in the magnitude of the stimulus, the amplitude continued to fall until respiration ceased temporarily when the angular acceleration was 1200 deg/sec^2 (see figure, A). However, in some animals an increase in the amplitude of the respiratory movements was observed with or without a simultaneous slowing of their frequency.

Significant changes in the frequency of respiration was observed starting from a stop-stimulus of 266 deg/sec^2 and higher ($P < 0.05$). With an increase in the strength of the stimulus to 1200 deg/sec^2, a direct relationship was observed between the magnitude of the stimulus and that of the response reaction. The respiration rate increased by 58-83% over its initial level. In all cases, the duration of the reflex changes in respiration did not exceed the first 10 sec after the stop-stimulus. In the course of the experiment, the initial respiration rate gradually fell, on account of the prolonged (about 1 h) fixation of the animal in the frame. However, the initial respiration rate before

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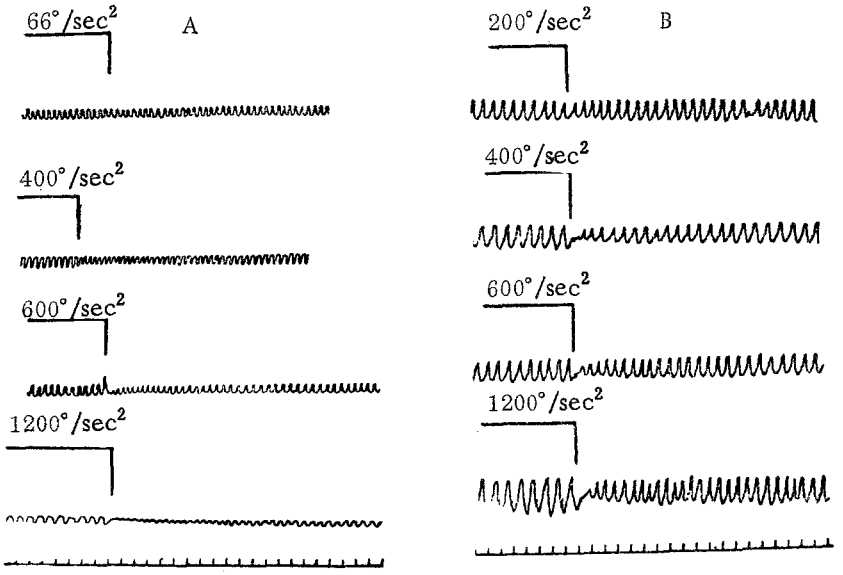
Scientific Director, Professor Yu. G. Grigor'ev (Presented by Active Member of the Academy of Medical Sciences of the USSR V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 9, pp. 19-22, September, 1966. Original article submitted June 30, 1965.



Change in amplitude of respiratory movements in rabbits during the action of angular accelerations of different magnitude: A) normal conditions; B) after bilateral labyrinthectomy.

application of the threshold stimulus (266 deg/sec^2) did not differ significantly from the respiration rate observed before application of maximal stimuli (800 and 1200 deg/sec^2).

In no case were significant changes found in the pulse rate. Possibly the stimuli applied were not strong enough to cause this autonomic reaction. In addition, the changes in the pulse rate could have been so brief in duration that they were not detected by the method of analysis.

The changes in the arterial pressure after stimulation of the vestibular apparatus were variable in character and not significant, apart from the reaction to the stop-stimulus of 800 deg/sec^2, when during the first 10 sec after its application a fall of 12 mm in the arterial pressure was observed. During rotation at uniform velocity (for 10 sec before the stop-stimulus) no regular changes were found in the arterial pressure.

During the further investigation of the problem, a series of experiments was carried out which differed from the first series in two respects: first, the arterial pressure was measured for 1.5 min after the stop-stimulus at intervals of 20 sec (the first, third, fifth, seventh, ninth 10-sec), and second, the pressure was measured in the brachial artery and not in the carotid. In this series of experiments, the number of cases of a fall of pressure after rotation increased steadily with an increase in the strength of the stimulus. Meanwhile, the number of cases when the pressure was unchanged became smaller. The number of cases of an increase of pressure remained small throughout, and showed hardly any change with an increase in the strength of the stimulus. Hence, when the pressure was measured in the brachial artery, the vestibulo-autonomic reaction was revealed more clearly than when it was measured in the carotid artery. This may be explained by assuming that the results of these measurements were influenced by reflex changes in the circulation arising following compression of the carotid artery by the cuff and associated with temporary interruption of the blood flow to the carotid sinus.

A significant fall in the arterial pressure took place during the first 10 sec after rotation, starting with an angular acceleration of 600 deg/sec^2 (the threshold level of the stimulus). With an increase in the strength of the stimulus, the magnitude of the reaction increased, i.e., a clear tendency was present for the arterial pressure to fall after rotation, corresponding to observations made by other authors [4,8,12, etc.]. The extent of the fall of pressure was 9.6-17.2% of the initial value.

Repetition of the same series of experiments to determine the reproducibility of the results revealed higher values of the thresholds (for a change in the respiration rate 600 deg/sec^2, for a change in the arterial pressure, 800 deg/sec^2). Evidently the thresholds of the vestibulo-autonomic reaction, even in healthy animals kept in normal conditions, may vary widely. Another factor which was possibly relevant was that this repeated series of experiments, unlike the first, took place during the autumn-winter period.

The autonomic reflexes described above did not develop in all animals. Of the 92 animals in the experimental group, no changes in the recorded autonomic indices were found in 17. In a further 14, the normal strength relationships were upset, for equal reactions were observed to stimuli of different strength, or a greater reaction was observed to a weaker stimulus.

The results of the control series of experiments on the labyrinthectomized animals showed that after bilateral labyrinthectomy, no significant changes developed in the autonomic indices of the animals studied in these experiments in response to vestibular stimulation. However, a change in the amplitude of the respiratory movements was observed (see figure, B) although rather less in degree than in normal animals. This suggests that the changes in the amplitude of the respiratory movements observed in rabbits during the action of angular accelerations are extralabyrinthine in origin and are only partly connected with stimulation of the vestibular apparatus.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of the first issue of this year.
