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CHANGES IN SPONTANEOUS ACTIVITY AS A MEASURE OF SENSITIVITY TO ROTATION IN THE WHITE RAT

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SUMMARY PAGE

THE PROBLEM

To investigate and measure the sensitivity of white rats to rotation using spontaneous activity as an index.

FINDINGS

Fifty-six unrestrained rats were individually exposed to a rotation speed between 0-18 RPM. Their activity was measured using a fourpoint scale: 0) no activity, 1) grooming and sniffing, 2) moderate running, and 3) rapid running. Amount of activity decreased as a function of rotation speed from 6 to 14 RPM, where it reached a lower limit plateau. Rate of decline within this speed range was also directly related to angular velocity. Postrotation activity was suppressed up to five minutes. The rats showed considerable sensitivity to Coriolis stimuli generated during rotation at constant angular velocities. A relationship was found between duration and magnitude of stimulation. These findings are encouraging for the use of behavioral methods in studying sensitivity to motion.

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INTRODUCTION

The development of behavioral and physiologic measures of the effects of rotation on subhuman species for comparative purposes is a continuing problem in vestibular research. Predominantly physiologic symptoms such as nystagmic eye movements, sweating, pallor, vomiting, et cetera have been used widely to measure responses by man and animals to rotation (6,8,12,14,17). Although graded behavioral changes served to describe stages of canal sickness in squirrel monkeys and chimpanzees, vomiting was relied on to determine susceptibility thresholds to rotation (12,14).

Subhuman species like the white rat, which do not openly manifest these physiologic symptoms, have been considered as either insensitive to vestibular stimulation or refractory to practical measures of rotational effects. However, it is possible that these animals would show sensitivity to rotation through behavioral traits and that appropriate behavioral changes would function as a practical measure of sensitivity.

Since freely moving rats engage in a variety of spontaneous responses to their environment, e.g., from grooming and sniffing to rapid locomotion, it appeared that the animal's activity could provide the dependent variable for assessing rotation effects. The same variable has been utilized by Bindra (1) to assess the results of drugs on white rats. It was found that the physiological changes induced by the drugs could be sensitively measured by modifications in behavior patterns.

The purpose of this experiment was to investigate and measure the sensitivity of white rats to rotation using spontaneous activity as a behavioral index.

APPARATUS AND PROCEDURE

The subjects were 56 male albino Sprague-Dawley rats, three to four months of age. The animals were purchased in small lots from the Sprague-Dawley colony in Wisconsin and maintained in the Naval School of Aviation Medicine Laboratories.

The apparatus consisted of what might be termed a closed field for measuring activity. The closed field is intended to elicit a reasonable amount of spontaneous or exploratory activity from the rats, in contrast with the open field which characteristically reduces activity and produces other types of emotional behavior. The field was an enclosed area 2 feet square with 6-inch sides made of clear Plexiglas. A removable opaque cover with air holes reduced the illumination in the field and prevented the rat's escape. The closed field was mounted on a rotation turntable with speeds ranging from 0.17 to 28.0 RPM with a precision of $\pm$ 2 per cent. The height of the turntable was fixed to allow a seated observer convenient observation through the side of the field.

In order to investigate activity changes, five to eight randomly selected animals were individually tested at one of the following constant angular velocities: 0,2,4,... 18 RPM. Each rat was used only once to avoid possible adaptation. The animals were run between 7:00 and 10:00 P.M. to take advantage of their increased night-time activity. The test room was dark except for a 50-watt red safety light located 5 feet from the rotation platform. The activity of each rat was measured during the prerotation, rotation, and postrotation periods. The duration of these three periods was six, six, and ten minutes, respectively. The postrotation session was longer to obtain data on the duration of the rotation effect. Three to four animals were run each evening, and at least two rotation conditions were employed to avoid any systematic bias. Three rats which froze continuously through the baseline period were discarded.

The activity of the rat was measured by observations taken systematically over time (cf. 2). The subject was observed and an activity score assigned for alternate ten-second periods. Thus, three activity scores, representing thirty seconds of observed behavior, were obtained each minute. The median activity per minute was then obtained for each group of rats at each rotation speed.

The scoring system was as follows:

3 - The highest level of activity. The rat ran rapidly and continuously in the field.

2 - The animal walked around, occasionally stopped and examined the field.

1 - The rat groomed, or scratched but remained fixed in one spot.

0 - Absolutely no movement observable. The rat held a "freeze" position.

The experimenter made an integrated judgment to assign a single score for a ten-second period. The use of half units (0.5, 1.5, et cetera) to modify the basic score provided a more finely graded continuum. Three personnel from the laboratory scored the rats at different times.

Thirty seconds after the rat was placed in the activity field, the first ten-second observation period began. After six minutes of baseline activity, the table was accelerated in two to three seconds to the predetermined rotation speed. Upon completion of this phase, the table was rapidly decelerated (two to three seconds) to 0 RPM. There was a thirty-second nonscored interval after starting and stopping rotation to permit angular acceleration effects to subside.

RESULTS

The six-minute prerotation period provided a baseline for each group. Since there were small differences in baselines of the different groups, the effect of various speeds on the animals is expressed directly as the ratio of activity during and after rotation to activity before rotation. Figure 1 presents the ratio of total rotation activity/total prerotation activity for all groups of subjects as a function of RPM. A smooth curve has been drawn through the experimental points. A slight increase in activity occurred at very low rotation speeds. Activity scores declined sharply after 6 RPM until reaching a plateau at about 14 RPM. The plateau shown in the figure after 14 RPM is the result of the scoring technique having reached its limit. In this range, the measure can no longer detect degrees of sensitivity, if there are any.

The time-course of activity changes for representative groups of animals is presented in Figure 2. Each point on the graph represents a group's median activity per minute. By the second minute of rotation exposure, animals at 10 RPM or above showed a sharp drop in activity rates. At speeds above 6 RPM the rate of activity decline was directly related to the rotation velocity. It can be seen in the figure that the control group showed a small decrease in activity during the twenty-two-minute session. The decline was most likely due to habituation to the box with an attendant reduction in exploratory responses.

It is clear from the curves in Figure 2 that both duration and speed of rotation were variables contributing to the animal's activity decline. This suggests the possibility of determining the various combinations of speed and exposure time which are equally severe as measured by activity change. Campbell and Kirby (3) have previously demonstrated that equal aversion contours can be plotted for a noxious stimulus such as electric shock. Figure 3 presents an "equal effect of rotation contour"; i.e., all points on the curve represent an equal reduction in activity. The points represent the time at which the activity of the different groups decreased by 30 per cent (reductions to other levels produce similar functions). The figure demonstrates, for example, that 1.3 minutes of rotation at 12 RPM produced a decrease in activity equivalent to three minutes of rotation at 8 RPM.

The animals rotated at 8 RPM or higher showed continued suppression of activity as long as five minutes after rotation. This can be seen in Figure 4 which presents the ratio of activities between the first five postrotation minutes and an equal portion of the baseline period as a function of the experimental conditions.

DISCUSSION

Unrestrained rats, like squirrel monkeys, show considerable sensitivity to constant angular velocities. Although vomiting was never observed in these rats, a characteristic "freezing" posture was noticed at higher velocities. The statue-like rigidity of the pose, readily discriminable from other behavior, has also been observed and referred to as "rotational posture" by Griffith (9) in his research on the effects of

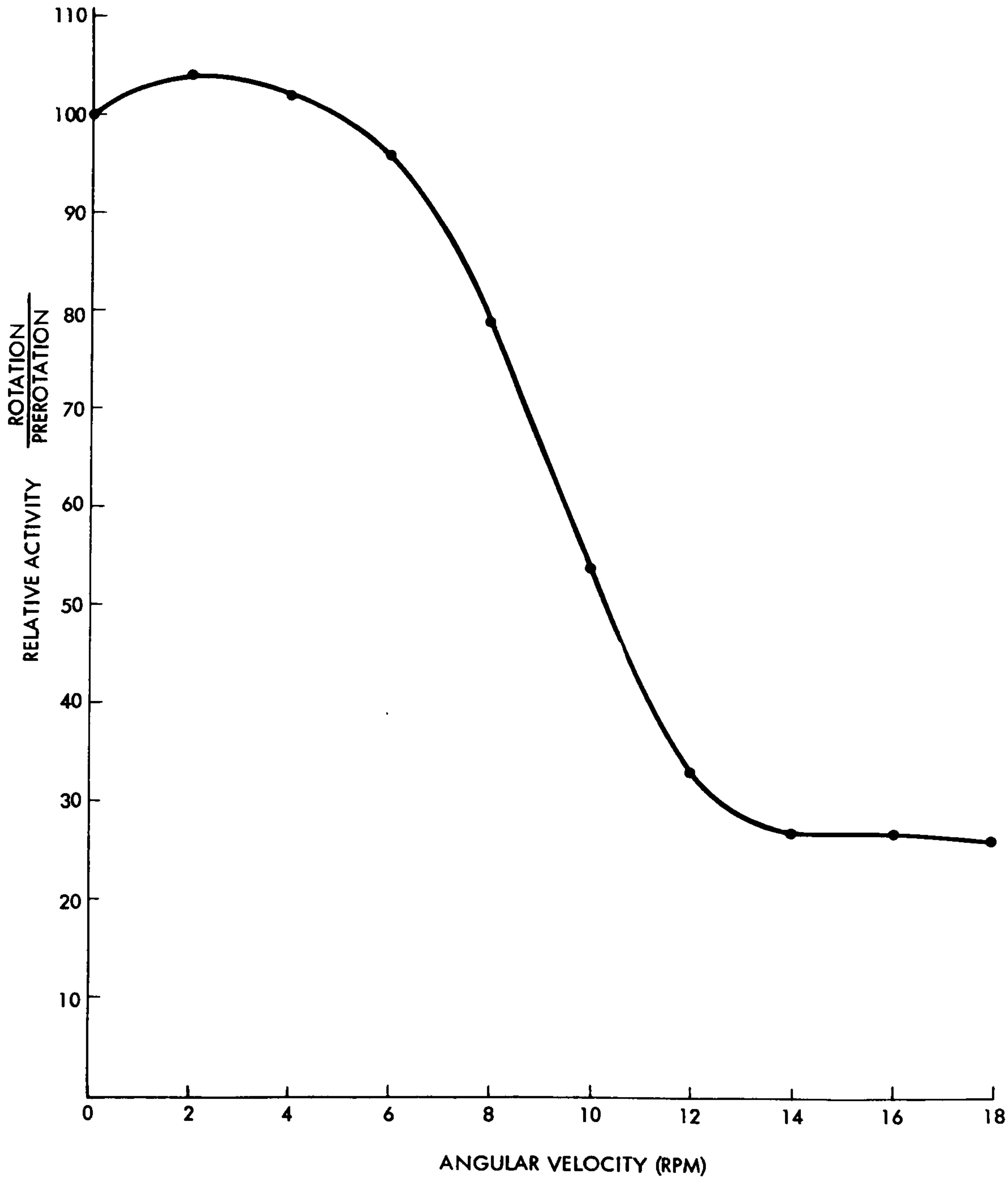

Figure 1

Relative Activity as a Function of Angular Velocity

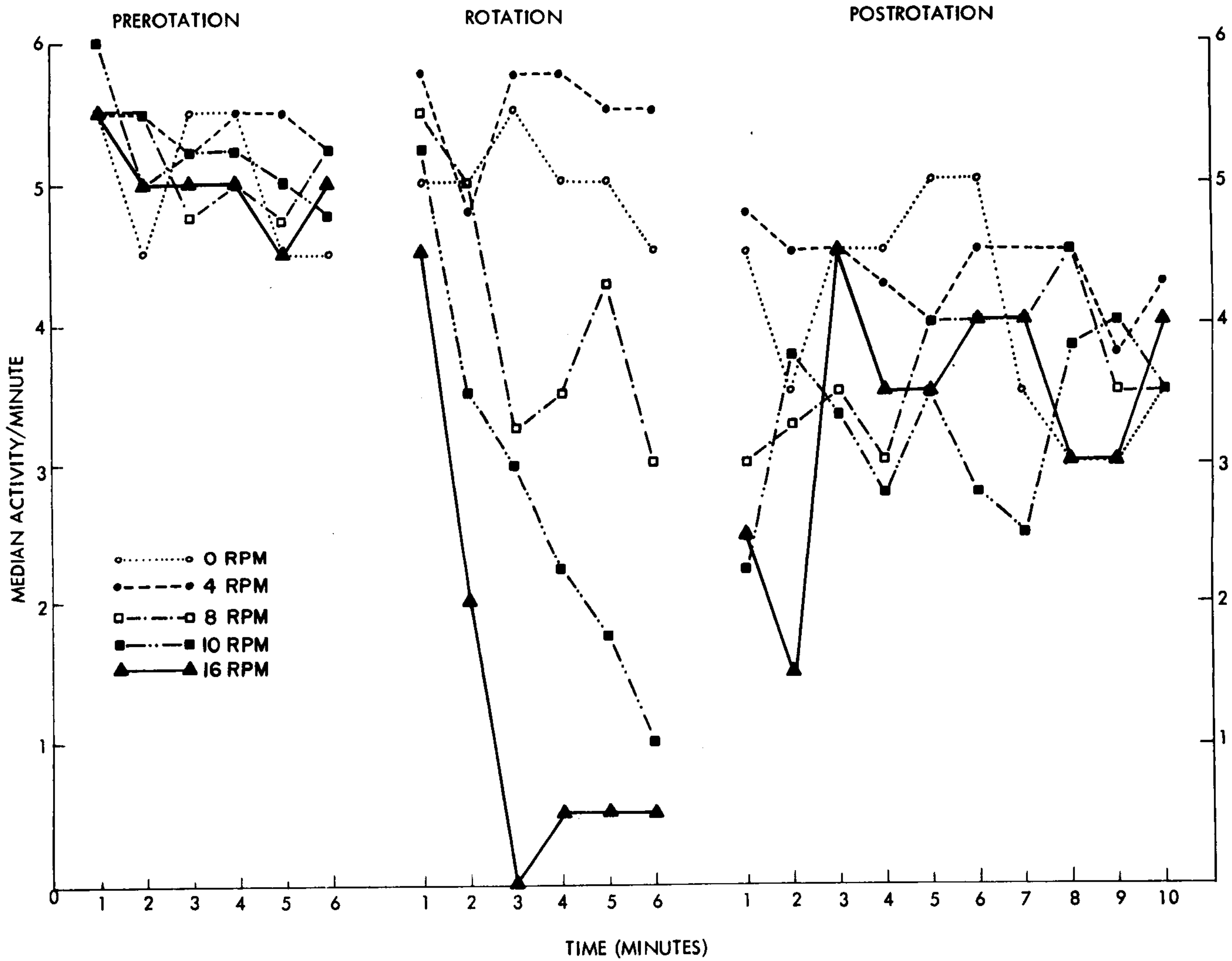

Figure 2

Time-Course of Activity for Representative Groups Prior To, During, and After Rotation

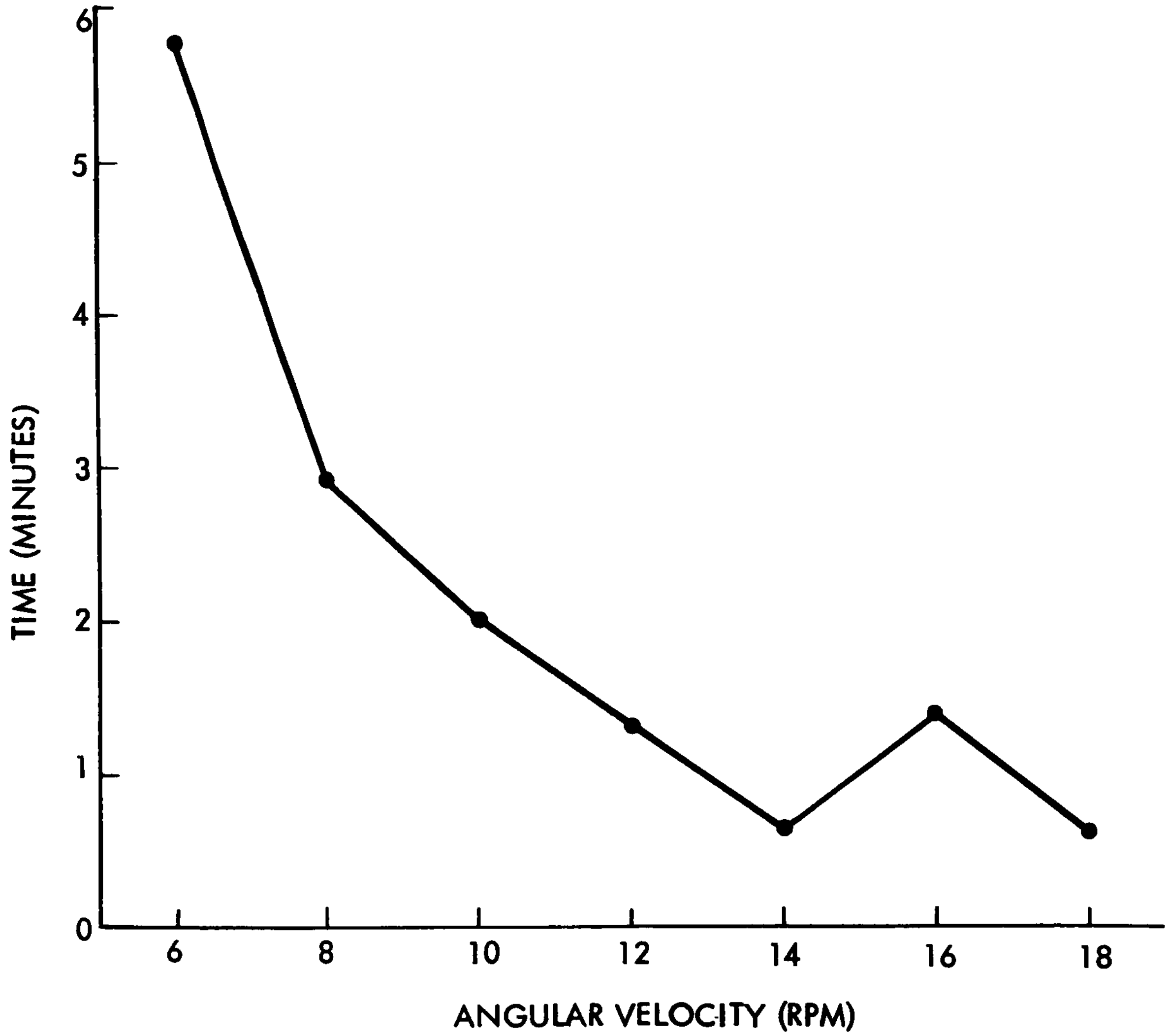

Figure 3

Duration of Rotation Exposure Required to Reduce Activity by 30% at Various Rotation Speeds

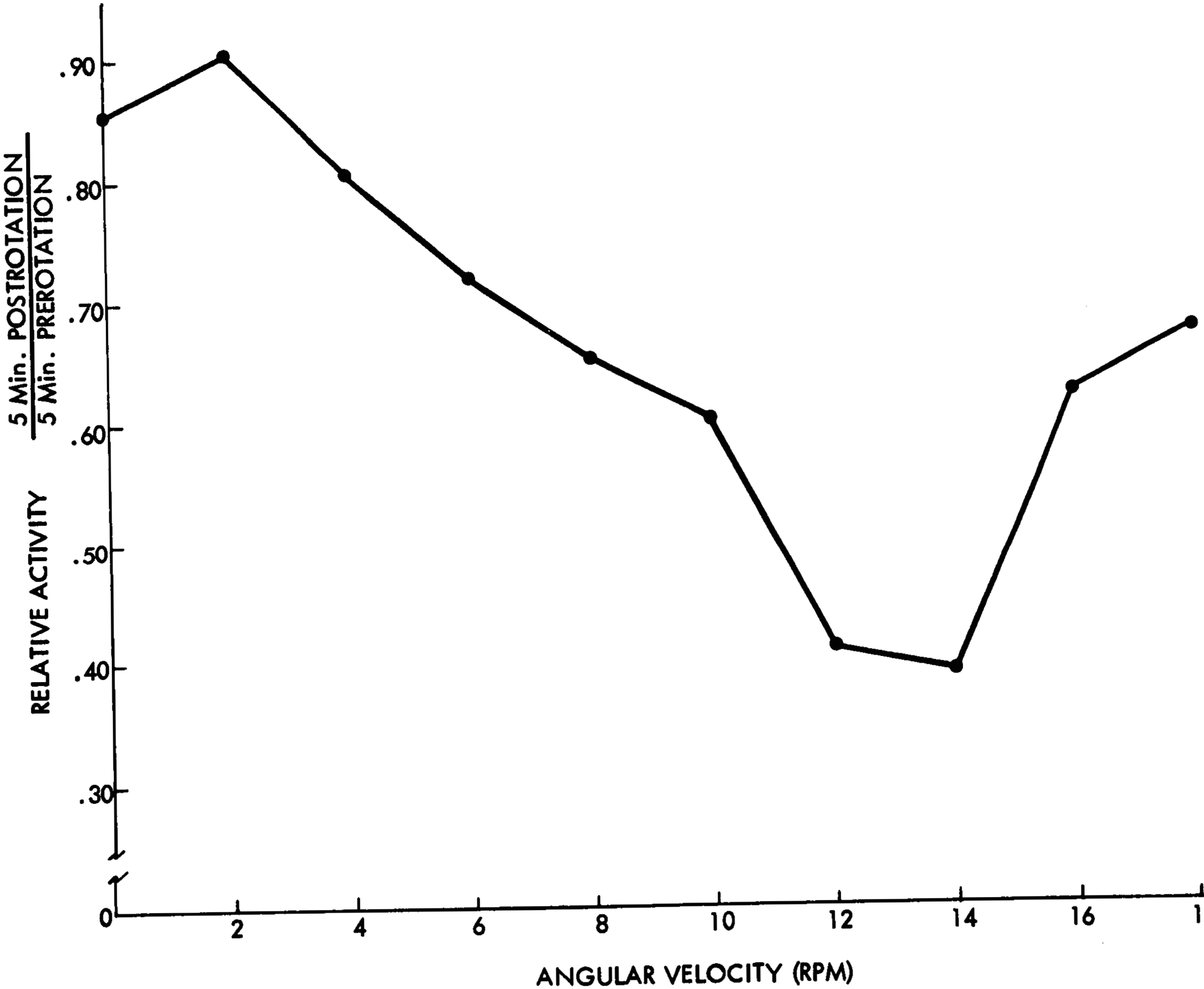

Figure 4

Five Minute Postrotation Activity as a Function of Rotation Speed rotation on nystagmus in the rat. That a laboratory animal as well studied and genetically controlled as the albino rat shows sensitivity to rotation suggests that it may be a useful subject for comparative vestibular research.

The question arises as to what factors are responsible for the reduction of activity. It is apparent from the slow time-course that the changes were not simply the result of the acceleration to the preset speed. A more likely variable was the Coriolis force which is a major source of vestibular input when the position of the head is moved relative to the rotating coordinate system of constant angular velocity (11). The Coriolis input is directly related to the velocity and magnitude of the subject's movement with respect to the rotating environment. Evidence presented in another study (15) demonstrated that the slight amount of G-forces present (maximum resultant G of 1.01) could not account for the observed changes and that the effects described were most likely attributable to Coriolis forces. The "Coriolis phenomenon" in man, which is of considerable importance for aspects of space medicine, has been the subject of intensive and continuing exploration by Graybiel and colleagues (4-7,10,13). In terms of labyrinthine mechanisms, Coriolis effects are presumably mediated by the semicircular canals rather than the otolith organs, hence the term "canal sickness"(6). By way of species comparison, canal sickness due to Coriolis acceleration has been reported for chimpanzees and squirrel monkeys (14).

The reason for the peculiar change in the postrotation activity suppression following exposure at 16 and 18 RPM shown in Figure 4 is not immediately clear. One possibility is that the animal was "thrown" into activity by the strong deceleration forces when the wheel was abruptly halted from high speeds. The animal could then quickly discriminate the lack of noxious Coriolis forces and resume its activity. Animals decelerated from slower speeds would have to emit several movements before learning that the aversive stimuli had been removed. Another possibility is that, due to the pronounced suppression of activity in the higher RPM groups, they were essentially recovering from the rotation effects before rotation ceased. The activity of the rotated animals recovered to the level of the control group after six to eight minutes.

The "equal effect of rotation curve" demonstrates that the behavioral response to rotation can be assessed as a joint function of duration and magnitude of rotation. The question arises as to why it took longer to obtain an equivalent activity decrease at 8 RPM than at 14 RPM. Coriolis input is generated by the rat when it moves in the rotating field. Accordingly, the postural freezing and reduction in activity can be considered as a learned response resulting from the reinforcement due to reduction of the Coriolis force which occurs when the head is held fixed. On the other hand, the decreased activity can also be viewed simply as a direct physiological response to "sickness" from rotation. Thus, the physiological effects of vestibular stimulation may accumulate within a certain period until they are equivalent to those produced by a 14 RPM stimulus over a briefer period. Alternatively, since the 8 RPM stimulus is less noxious than the 14 RPM, it may be that the more slowly rotated group was less motivated to learn to avoid the stimulation. This experiment does not discriminate among these possibilities and answer the question raised. The "equal effect contour" also points out the fact that, after only three minutes of rotation at various speeds, the groups can be discriminated in terms of activity changes.

The small but consistent increase in activity at low angular velocities is difficult to explain. One possible interpretation is that it represents a transitory state which would eventually give way to cumulative Coriolis effects. To investigate this possibility, a group of rats was rotated at 4 RPM for fifteen minutes. The activity of the rotated group was found to remain slightly higher than a nonrotated control group for the same length of time. Within the explored time range and low rotation speed, the effects of rotation apparently were not cumulative.

To assess the generality of the activation phenomenon seen in the 4 RPM group, the relative activity data for the first minute of rotation was then examined for all nine groups (2 to 18 RPM). An initial increase in activity occurred in all but the high speed (12 to 18 RPM) groups for this period of time. At high rotation speeds, the Coriolis effects apparently occurred quickly enough to mask the initial response to rotation. At more moderate speeds (8 to 10 RPM), the amount of activity initially increased, then diminished during continued rotation exposure. Therefore, the increased activity of the rats seems to be a real phenomenon and may represent their attempt to escape an unusual vestibular stimulation.

These findings would seem to indicate that there is a certain Coriolis sensitivity threshold involved. It is difficult to assign an absolute threshold for this Coriolis sensitivity. At 7 RPM a 10 percent decrease occurred in baseline activity and at 9 RPM a 35 percent decrease for a five-minute rotation exposure. Therefore this range (7 to 9 RPM) represents a major transition in behavior. It is of interest that Riccio and Thach (16) using operant conditioning techniques have found that a major decrease in frequency of bar-pressing occurred between 10 and 14 RPM. In spite of a number of differences between the two experiments, both produced somewhat similar descriptions of the sensitivity of the rat to rotational forces.

The activity test used in this experiment has been found to provide a sensitive and quantitative index of rotational effects on rats. The system should therefore be useful for vestibular research. In addition, a long training period for the animals is not necessary. These features also recommend the system for its application in research concerned with pharmacological modification of sensitivity to motion sickness. The system has already proven useful in such an application by measuring the modification of rotation sensitivity through unilateral destruction of the hair cells of the labyrinth in rats by streptomycin sulfate injection (15).

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