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BY MEANS OF CONTROLLED HEAD MOVEMENTS

Ashton Graybiel and Charles D. Wood

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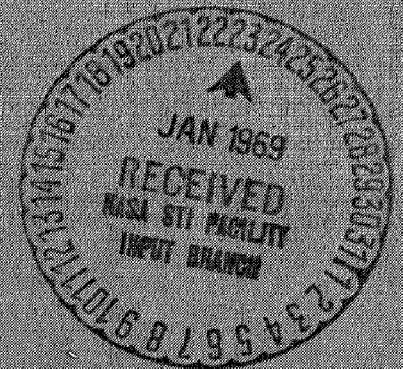


JOINT REPORT



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SUMMARY PAGE

THE PROBLEM

Two attempts to telescope, in time, vestibular adaptation in a slow rotation room (SRR) were made to determine the easiest and quickest means of preventing the appearance of SRR sickness at a terminal velocity of 10 rpm. Three subjects in each experiment were exposed to unit increases in rotational velocity at which time they made several hundred experimenter-directed head movements. Prior to cessation of rotation standardized tasks were performed to determine the degree of transfer of adaptation acquired from the "directed" movements.

FINDINGS

The results demonstrate that the process of homeostatic adaptation can be greatly speeded up through experimental control of head movements although a large number of "limited" head motions must be made to ensure transfer of adaptation to general activities. Some idea was gained regarding the number and excursion of head movements required at each unit increase in rpm for adaptation and overadaptation at terminal velocity.

INTRODUCTION

In a recent experiment (2) overt symptoms of motion sickness, with the probable exception of drowsiness, were prevented in normal subjects living in a room rotating at 10 rpm when this terminal velocity was reached in nine incremental steps over a period of 16 days. This pointed the way to shorten the time required to effect homeostatic adjustment by substituting experimenter-controlled head movements for those made incidentally by the subject in the course of the day's activities. Provided the angular velocity of the room was kept sufficiently low to prevent the appearance of overt symptoms, fatigue would be the only factor limiting the number of head movements that the subject could make, and the processes of adaptation involving vestibular systems would be accelerated. Moreover, except at such times when the subject would engage in undirected activities, the experimenter would have quantitative control over the generation of Coriolis acceleration, thus permitting duplication of an experiment and the determination of individual differences in response to a standardized stress.

What follows describes two attempts to telescope, in time, vestibular adaptation in a slow rotation room (SRR). The basic objective was to determine the easiest and quickest means of preventing SRR sickness at 10 rpm, solely by means of graduated increases in stressful acceleration.

METHOD

The experimental design problems included 1) standardizing "head movements" (H-M's), 2) patterning incremental increases in the stressful accelerations, and 3) determining the degree to which the adaptation acquired by making "limited" H-M's transferred to the unlimited H-M's involved in "undirected-general-activities" or "standardized tasks" designed to produce maximal stress.

There are a number of variables to consider when limited H-M's are used. These include 1) the number of planes in which the movement is made, 2) the excursion of the movement in degrees of arc in each plane, 3) the velocity of the movement, 4) the delay periods at the end of each excursion, 5) the nature of the movement, e.g., flexion at neck, waist, or both and whether active or passive, 6) the number of H-M's, and 7) the orientation of the subject with reference to the axis of rotation of the room. Generation of Coriolis accelerations is independent of the distance of the subject from the center of rotation, and there is some evidence that under conditions similar to those in this experiment, differences in levels of centripetal force do not significantly affect susceptibility to motion sickness. Consequently, with H-M's standardized, variations in level of stress can be effected through control over the angular velocity of the room.

Previous experience had indicated that a relatively large number of rotations of the head should be made in more than one plane at every incremental increase in rpm. A characteristic sensation of tumbling or rotation persisting after the end of a head

excursion, when the movements are made while the subject is rotating at high angular velocities, suggested there might be some advantage to increasing the time required as a function of increase in rpm of the room. With this in mind, H-M's were paced with a metronome set for 2 seconds at velocities of 1 to 6 rpm, 4 seconds at 7 to 9 rpm, and 6 seconds at 10 rpm. A head movement consisted in a motion away from and return to the upright. There was also some evidence from past experience that the first increment in angular velocity of the room might safely be larger than the second because everyone possessed a certain "vestibular functional reserve" protecting him from symptoms of motion sickness. Moreover, the notion prevailed that after a stepwise increase of angular velocity to 5 or 6 rpm had been reached, subsequent increments might safely be increased in magnitude greater than 1.0 rpm.

Standardized tasks were devised to test for the effectiveness of transfer of adaptation at terminal velocity. One task consisted of tossing tennis balls across the room into a basket, first in one direction then the other, and included retrieving balls falling on the floor. In the second task the subjects walked a line heel-to-toe back and forth between the center of the room and periphery. The third was a task in which 25 nuts and bolts were removed, one at a time, from a board at station "1" and five of them inserted at each of five other stations, each station differently placed; this required the subject to make extreme head and body motions out of the plane of the room's rotation. The fourth task consisted of making the standardized H-M's for ten minutes. The subjects rotated from one task to another about every 10 minutes.

It was anticipated that 250 to 500 H-M's could be made without a rest period. If symptoms appeared, consideration was to be given to increase the number of H-M's at or below the velocity at which symptoms were experienced.

SUBJECTS

Three volunteer subjects participated in each experiment. All six were college students selected mainly on the basis of clinical fitness, as revealed by a routine flight physical examination, and not on the basis of susceptibility to motion sickness. Results of tests with relevance for the sensory organs of the inner ear showed that none had any significant loss in hearing, all had normal threshold caloric test (6) responses and ocular counterrolling indices (7,8), and scores made on a postural equilibrium test battery (1) were within the normal range.

DEVICES

The experiments were conducted in a rotating room approximately 15 feet in diameter and 7 feet high, which was provided with living facilities, the necessary laboratory equipment, and a communication system. Three chairs were secured directly facing and equidistant from the center of rotation. When the subject was seated upright, the approximate distance from the center of his head to the center of rotation

was 36 inches. The chairs were provided with comfortable arm rests and a removable head rest. The subject could be restrained by a lap belt or by a shoulder harness.

PROCEDURE EXPERIMENT I

In this experiment the subjects' shoulders were restrained, and the movements consisted essentially of flexion of the head from the upright and return: forward, return, backward, return, leftward, return, and rightward, return, always in the same order. A padded frame limited the motion in all directions except backward. The head was flexed through an arc of about 45° left and right, about 70° forward, and about 35° backward. The expectation was to require 1000 H-M's at 1 rpm and at each unit increase in velocity of the room up to and including 10 rpm. After making the H-M's at terminal velocity the subjects alternately carried out tasks 1, 2, and 4 (described above) to determine the degree of transfer of adaptation.

At least one observer monitored the subjects at all times. Recording procedures found to be useful in previous experiments were used, and attention was given to the activities of the subject which were not experimenter controlled. The diagnostic criteria and numerical scoring system (3) for the full range of severity of motion sickness symptoms were used (Table I).

PROCEDURE EXPERIMENT II

In this experiment the subjects were secured by means of a lap belt, and the movements involved not only flexion of head but also movement of the trunk at the waist. The back of the chair limited backward motion to about 40° , but the movements sideways were about 70° and those forward, 90° . Based on the results of Experiment I, the need for making 1000 H-M's at each unit increase in the room's velocity was deemed advisable. Tasks 1, 2, and 3 were used in testing transfer effects at terminal velocity.

RESULTS AND DISCUSSION

EXPERIMENT I

The stress profile in the first experiment and a summary of the approximate levels of severity of symptoms are depicted in Figure 1. None of the subjects experienced symptoms of motion sickness or fatigue at 1 rpm after making 1000 H-M's, divided into four sessions of 250 each interrupted by brief rest periods. The ease with which the 250 head movements were made suggested that 500 would not be too many in one session.

After making 500 H-M's at 2 rpm subject TA was sleepy and remained quietly in his chair, while the other two subjects were animated and "stretched" their legs. After the second session of 500 more H-M's (total of 1000) there was a break for luncheon; all ate well, but TA appeared sleepy. It is worth noting that anorexia is not always

Table I
 Diagnostic Categorization of Different Levels of Severity of Acute Motion Sickness

Category	Pathognomonic 16 points	Major 8 points	Minor 4 points	Minimal 2 points	AQS* 1 point
Nausea syndrome	Vomiting or retching	Nauseat II, III	Nausea I	Epigastric discomfort	Epigastric awareness
Skin color		Pallor III	Pallor II	Pallor I	Flushing/Subjective warmth \geq II
Cold sweating		III	II	I	
Increased salivation		III	II	I	
Drowsiness		III	II	I	
Pain					Headache
Central nervous system					Dizziness Eyes closed \geq II Eyes open III

Levels of Severity Identified by Total Points Scored					
Frank Sickness (S)	Severe Malaise (M III)	Moderate Malaise A (M IIIA)	Moderate Malaise B (M IIIB)	Slight Malaise (M I)	
\geq 16 points	8 - 15 points	5 - 7 points	3 - 4 points	1 - 2 points	

*AQS = Additional qualifying symptoms. + III = severe or marked, II = moderate, I = slight.

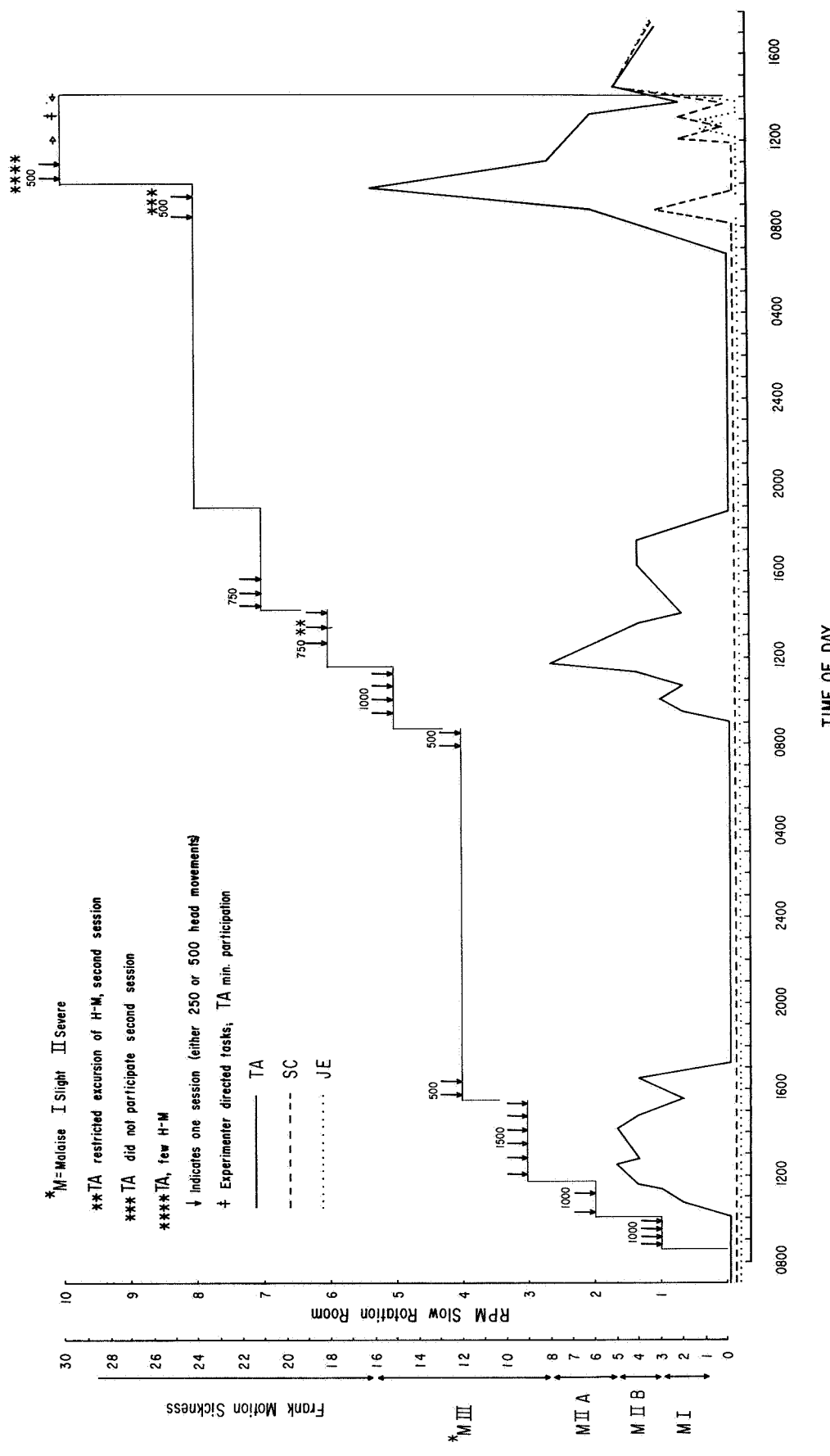


Figure 1
 The Stress Profile in the SRR and Manifestations of Motion Sickness in Three Healthy Subjects Exposed to Rotation for Over Two Days

among early motion sickness symptoms. It was decided to return to the shorter sessions with more rest periods in the hope of aiding TA.

After 250 H-M's at 3 rpm, TA specifically denied epigastric symptoms but fell asleep during the rest period; SC and JE were alert and symptom free. On completion of four sessions (1000 H-M's) at 3 rpm TA had not recovered, and it was decided to increase the total number of H-M's for this angular velocity to 1500. After 250 more H-M's in the next session TA fell asleep, but after the last session (250 H-M's) at 3 rpm he felt better:

Rotation speed was increased to 4 rpm while the subjects rested with heads fixed. All appeared well and none reported having any symptoms prior to resuming H-M's. Two sessions (500 H-M's total) completed the metronome-paced H-M's for the first day. TA reported that he felt very well only as long as he remained quiet; the other subjects were symptom free. No restrictions were placed on general activities although TA imposed his own. The long period during the evening and night with minimal stress permitted recovery without loss of adaptation. All of the subjects slept well and next morning were in good spirits. The remaining two sessions at 4 rpm were completed without the appearance of overt symptoms.

The four sessions of 250 H-M's each at 5 rpm were completed before the break for luncheon. TA complained of epigastric discomfort throughout and was "queezy" at the end. SC and JE were symptom free. The room's velocity was increased to 6 rpm prior to luncheon.

During the first session at 6 rpm, TA was pale, drowsy, complained of epigastric discomfort and fell asleep during the first rest period. He restricted the extent of the motions during the second session, and his symptoms declined although epigastric distress remained. By this time it was clear that TA could not keep up with the other subjects, and a decision was made to allow him to participate as best he could and determine whether the others would adapt with fewer than 1000 H-M's. Only three sessions (750 H-M's) were required for adaptation at 6 rpm. TA continued to experience epigastric distress; the other two subjects remained fit and alert.

Only three sessions were required of the subjects at 7 rpm; these 750 H-M's were completed before the break for dinner. TA continued to experience epigastric distress; the other two were symptom free. All ate well. The velocity of the room was increased to 8 rpm after dinner. The evening was spent watching television. All slept well.

The morning of the third experimental day TA still complained of epigastric distress, indicating he had not recovered despite minimal stressing. After the first session of 250 H-M's at 8 rpm he reported drowsiness and epigastric distress; the others reported dizziness and drowsiness, their first complaints. All "wondered" when the experiment would end. After a rest period TA still appeared to be ill and did not participate in the second session; the other two subjects appeared fit and were symptom free. Only

500 H-M's were made at 8 rpm; SC reported mild symptoms but JE remained symptom free.

After the subjects' rest period, the room was accelerated from 8 to 10 rpm. TA attempted to make H-M's but quit; he frankly was motion sick, but did not vomit; the other two subjects were symptom free. Only SC and JE participated in the second and last session at 10 rpm. SC reported dizziness, but JE was symptom free after a total of 500 H-M's.

There was a long break before luncheon; TA did not move from his chair and refused food; SC and JE were up and about but ate little food. It was difficult to determine whether the general activities causing anorexia or "poor chow" accounted for the small amount of food eaten.

After luncheon a period of two hours was devoted to carrying out three of the standardized tasks described above. TA made the attempt but gave up; he was frankly motion sick. SC appeared pale and experienced epigastric discomfort and dizziness. JE complained of dizziness when tossing balls into a basket but reported no other symptoms.

After cessation of rotation all subjects were ataxic and all experienced dizziness when making movements involving rotations of the head. TA took dimenhydrinate for epigastric distress. SC induced vomiting to relieve a "heavy feeling in the stomach"; he was drowsy and napped and continued to experience dizziness on moving his head until about 1000 hours the second postrotation day. JE reported slight sweating, slightly increased salivation, and some anorexia but no definite epigastric awareness or discomfort; a slight headache persisted into the third postrotation day.

Comments

The findings in this experiment demonstrated the feasibility of substituting directed for undirected H-M's in the prevention of motion sickness in a rotating environment. The individual differences in susceptibility to acute SRR sickness were indicative of the subjects' differences in response to the programmed exposure to stress. By far the most susceptible of the three subjects TA became drowsy at a very low level of stress, and this was followed by more severe failure in homeostatic adjustment at higher rpm. It appeared that not only was he more susceptible than the other two, but also that his rate of homeostatic adjustment was slower. To ensure prevention of symptoms at 10 rpm in his case, a different program for the incremental increases in stress would be required.

There were small but significant differences between SC and JE in their adjustment to the stress. JE experienced trivial symptoms while making the H-M's at the nine incremental increases in level of stress and manifested no symptoms of motion sickness while carrying out the tasks at terminal velocity, indicating that transfer of adaptation was good. It is noteworthy that the total number of head movements per rpm was reduced after 5 rpm and that between 7 rpm and the standardized tasks at

terminal velocity, only 500 H-M's were made at 8 and at 10 rpm. This suggests that in the case of JE, either more H-M's than necessary for adaptation were made at velocities below 6 rpm or that homeostatic adjustment was more readily accomplished at the higher velocities.

The third subject, SC, differed from JE in his adjustment to rotation, mainly in making the transfer from limited H-M's at 10 rpm to the standardized tasks when he experienced symptoms. Although the symptoms were not severe, they represented a definite failure in homeostatic adjustment, and their aggravation on cessation of rotation caused him to induce vomiting.

EXPERIMENT II

It should be mentioned that during the course of this experiment, the air-conditioning unit for the section of the building housing the SRR failed around noon on the first day. As the building gradually became warmer, the small air conditioner in the SRR became inadequate and room temperature rose. Conditions remained tolerable with subjects in shorts until 0430 hours on the third day when the small unit failed. It was repaired but failed again at 0755 hours, and rotation was prematurely terminated at 0826 hours.

The stress profile in which 500 H-M's were made at each session and the level of symptoms experienced are shown in Figure 2; it can be seen at a glance that symptoms of motion sickness were trivial in two subjects and mild in the third.

During the first experimental day the subjects' only complaint was fatigue. This was mentioned after sessions 3 and 4 but not after 5 and 6, indicating that it was not progressive. The fatigue did not involve any specific region of the body. During the rest period after session 8, which was not long after luncheon, the subjects slept; the fact that they were alert during subsequent rest periods suggests that the drowsiness was not primarily of vestibular origin.

During the second experimental day all complained of fatigue after the first session and began the practice of lying on the floor during the rest period. After the first session at 8 rpm, RO appeared pale and experienced epigastric awareness but recovered in a short time; after the second session at 9 rpm, he again appeared pale but denied having any subjective symptoms. After the first and only session at 10 rpm, CA reported slight dizziness while making head movements and RO appeared pale. All were in high spirits over completion of this phase of the experiment.

The morning of the third day the room temperature was 90° F at 0530 hours due to failure of the air conditioning. At 0745 hours the air conditioner was operating, and at 0750 hours the subjects began alternately to perform the three standardized tasks. Within a few minutes the air conditioner failed again; at 0823 hours the tests were discontinued, and rotation stopped at 0826 hours. None of the subjects manifested any symptom of motion sickness.

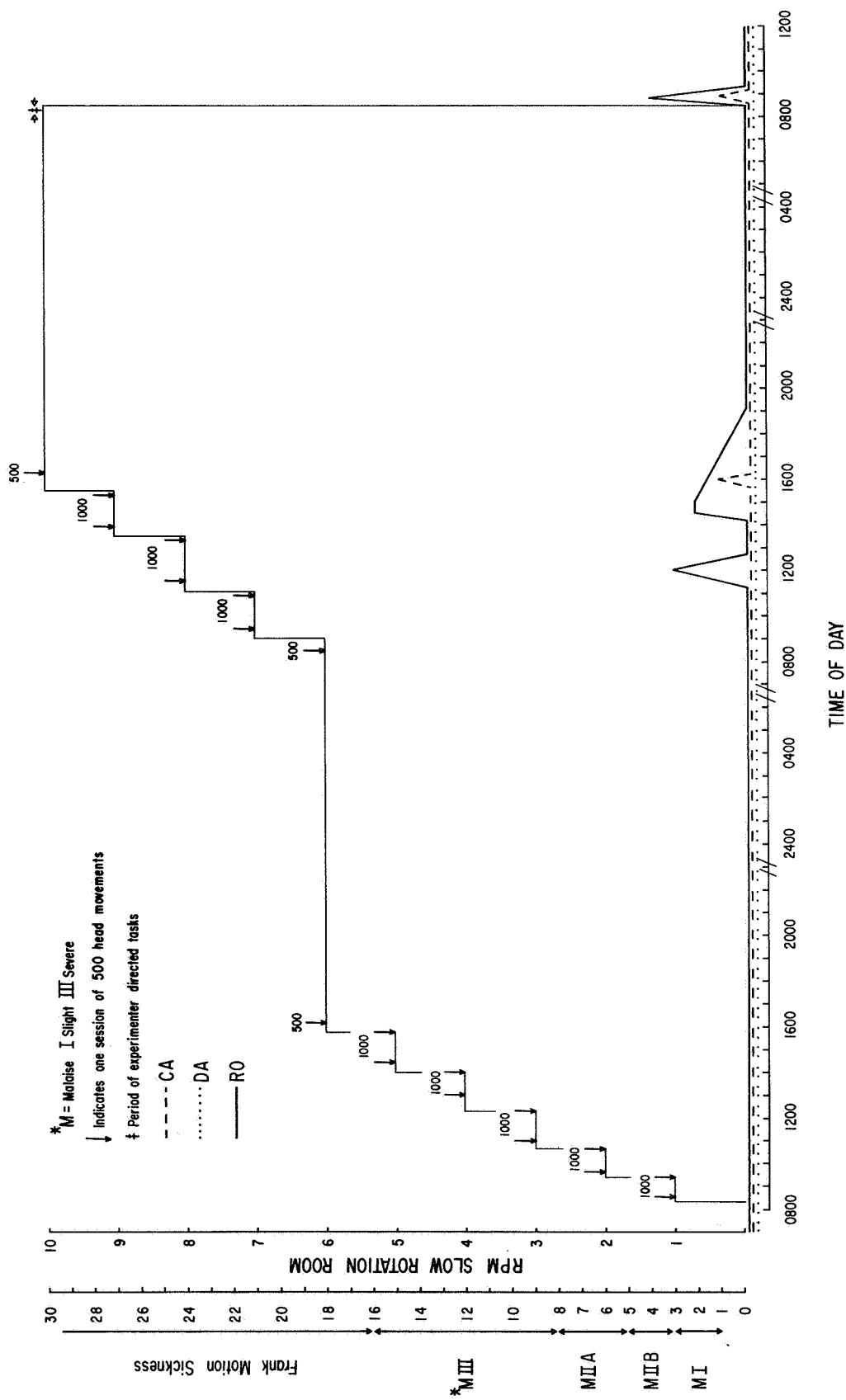


Figure 2

The Stress Profile in the SRR and Manifestations of Motion Sickness in Three Healthy Subjects Exposed to Rotation for About Two Days. The Large Number of Head Motions Accounted for the Rapid Adaptation.

After cessation of rotation all of the subjects were ataxic but only for periods measured in minutes. CA reported slight "light headedness," DA was symptom free, and RO experienced epigastric distress for a brief period.

Comments

Only one of the three subjects, RO, demonstrated a failure in homeostatic adjustment which was brief and mild in nature. It is worth noting that this occurred at high rather than low rotational velocities and did not support the notion that adjustment to the rotating environment is more readily accomplished after 5 rpm has been reached.

Loss of air conditioning prevented an adequate test of transfer of adaptation; the period of 33 minutes for carrying out the standardized tasks was too brief to be certain that symptoms of motion sickness might not have appeared. Activities in connection with housekeeping and recreation over a period from 1900 to 2300 hours the evening of the second day and in carrying out standardized tasks for the final 33 minutes of rotation did not result in symptoms of motion sickness; thus, evidence was provided that adaptation was satisfactory for all practical purposes. Moreover, the fact that such symptoms were absent or trivial on cessation of rotation might be construed as additional proof of excellent adaptation.

Each subject was queried regarding complaints other than symptoms of motion sickness. None experienced muscular aches or pains and all used the word fatigue mainly to indicate boredom and monotony. The drowsiness experienced on occasion was not connected with the directed activities but with confinement, eating, and possibly warmth of the room. Although there is evidence that a warm (9) or warm and humid environment (10) does not significantly alter susceptibility to motion sickness, these observations involved brief, not prolonged, exposures to stress.

CONCLUSIONS

The findings in these two experiments extend our knowledge concerning the prevention of symptoms of motion sickness in a rotating environment and the underlying central nervous system mechanisms. It has been clearly demonstrated that the process of homeostatic adaptation can be greatly speeded up through experimenter control of head movements and velocity of the rotating room. Only limited excursions of the head in two planes were sufficient to bring about adaptation, although large numbers of these "excursions" were necessary. There was strong evidence that the standardized tasks were more stressful than the directed H-M's carried out for the same amount of time, but failure to count the H-M's involved in the tasks prevents estimating the ratio of effectiveness. It is also possible that more factors than the number of H-M's in carrying out the tasks were important. One inference is that standardized tasks might not only be far more stressful, but also far more effective in bringing about the homeostatic adjustment. There is proof from past experiments (4, 5) that a single H-M in one

"quadrant" is sufficient to evoke motion sickness and that adaptation is rapid; the extent of transfer to H-M's in other quadrants was not determined.

There was evidence that symptoms of motion sickness on cessation of rotation reflected the degree of overadaptation at terminal velocity. It is also noteworthy that the first definite symptom during exposure to very mild stress may be drowsiness. This is of practical importance in aerospace flight and points to the possibility of studying the underlying events and processes of drowsiness without other complicating symptoms being present.

In Table II are shown the relative rankings of the two groups of subjects when they were exposed to a brief test for susceptibility and their rankings during prolonged exposure to rotation (Experiments I and II). The results are clear cut in the case of TA. On the basis of the brief test it was anticipated that RO would be the least susceptible in his group during prolonged exposure; since he was the most susceptible instead, there are obvious limitations in extrapolating from brief to long exposures wherein secondary factors may play a larger role.

Some idea was gained regarding the number of limited head movements required at incremental increases in velocity for adaptation at a specified rpm and the nature of standardized tasks which best test the degree of transfer at terminal velocity. Many questions raised in the section on methodology remain unanswered; these include most of the variables mentioned in connection with head rotations and the phenomenon of overadaptation. More experimentation is needed to quantify all aspects of the time-course of adaptation during rotation and its decline under controlled conditions after cessation of rotation. These findings, when interpreted in the light of underlying central nervous system mechanisms, will be of theoretical interest.

Table II

Relative Rankings of the Six Subjects on Brief and Prolonged Tests of Susceptibility to SRR Sickness

Subject	Acute SRR Sickness (brief test)			Prolonged Tests
	RPM	No. H-M's	Level Sym. Rank	
TA	7.5	60	M III 6*	Experiment I: Most by far SI. > least Least ----- Experiment II: Most SI. > least Least
SC	15.0	35	M III 5	
JE	20.0	70	M III 4	
RO	20.0	300	M I 1	
CA	20.0	300	M IIA 2	
DA	20.0	75	M III 3	

*6, most susceptible.

REFERENCES

1. Graybiel, A., and Fregly, A. R., A new quantitative ataxia test battery. Acta otolaryng., Stockh., 61:292-312, 1966.
2. Graybiel, A., Deane, F. R., and Colehour, J. K., Prevention of overt motion sickness by incremental exposure to otherwise highly stressful Coriolis accelerations. Aerospace Med., 39:1968. In press.
3. Graybiel, A., Wood, C. D., Miller, E. F. II, and Cramer, D. B., Diagnostic criteria for grading the severity of acute motion sickness. Aerospace Med., 39:453-455, 1968.
4. Guedry, F. E., Jr., Visual control of habituation to complex vestibular stimulation in man. Acta otolaryng., Stockh., 58:377-389, 1964.
5. Guedry, F. E., Jr., Collins, W. E., and Graybiel, A., Vestibular habituation during repetitive complex stimulation: A study of transfer effects. J. appl. Physiol., 19:1005-1015, 1964.
6. McLeod, M. E. and Meek, J. C., A threshold caloric test: Results in normal subjects. NSAM-834. NASA Order R-47. Pensacola, Fla.: Naval School of Aviation Medicine, 1962.
7. Miller, E. F. II, Counterrolling of the human eyes produced by head tilt with respect to gravity. Acta otolaryng., Stockh., 54:479-501, 1962.
8. Miller, E. F. II, and Graybiel, A., A comparison of ocular counterrolling movements between normal persons and deaf subjects with bilateral labyrinthine defects. Ann. Otol., 72:885-893, 1963.
9. Wendt, G. R., and Lindsley, D. B., Studies on motion sickness. Series A. Report No. 40. Part III. A note on an unsuccessful effort to investigate the effects of temperature on vestibularly induced nausea. Washington, D. C.: Civil Aeronautics Administration, Division of Research, 1944.
10. Wood, C. D. and Graybiel, A., The effect of environmental temperature on susceptibility to motion sickness. NAMI-1005. NASA Order R-93. Pensacola, Fla.: Naval Aerospace Medical Institute. In press.

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