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SUCCESSFUL TRANSFER OF ADAPTATION ACQUIRED IN A SLOW ROTATION ROOM TO MOTION ENVIRONMENTS IN NAVY FLIGHT TRAINING

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SUMMARY

Two flight students, grounded for the reason they were highly susceptible to motion sickness, completed their training after gradually adapting to 10 rpm, achieved by executing head movements during small stepwise increases in angular velocity. Subject 1 executed a total of about 77,000 head movements within a period of five months and Subject 2 executed about 108,000 head movements within a period of 42 days. The transfer of the adaptation acquired in the laboratory to most motion environments aloft was good; the notable exception involved weightless maneuvers in the case of Subject 1. Both were on flight status when contacted recently. The opportunity was taken to assess the current motion sickness susceptibility in Subject 1 in the fall of 1975. He reached our (mild) motion sickness endpoint, in the rotating room, at 17 rpm; the average endpoint is 7-8 rpm. Some practical and theoretical implications are discussed.

INTRODUCTION

If a person riding in a slowly rotating room makes a head movement outside the plane of the platform's rotation, cross coupled accelerations are generated which stimulate the vestibular apparatus in an unusual way. In the stationary state, head movements are associated with a pattern of accelerations that produce vestibular sensations consistent with the visual and propioceptive sensations associated with these head movements through past experience. By adding rotation, the vestibular sensations associated with the same head movements now include those sensations produced by the cross coupled accelerations. This produces a situation where the vestibular sensations are no longer consistent with the past visual and proprioceptive sensations. The subject's reactions to this unusual state can be grouped into two classes (1). The first class consists of reflexive reactions such as nystagmus, tumbling or turning sensations, and certain visual illusions. The first class seems to be a direct response to vestibular stimulation. A second class of responses less directly related to the vestibular stimulation constitutes the signs and symptoms of motion sickness. Inasmuch as these signs and symptoms have their immediate origins in non-vestibular systems, one must postulate a facultative linkage between vestibular and non-vestibular systems as an important element in the causation of this form of motion sickness (1). The signs and symptoms arising from this unusual vestibular stimulation have been well studied and a sensitive grading method is available (2).

It has been shown that subjects who perform sufficient head movements at one rpm increments can asymptomatically reach high angular velocities which would otherwise be intolerable (3). By having the subject execute a schedule of head movements at each increment in angular velocity, one has a simple method of providing adaptation to rotation. This scheme is called an incremental adaptation schedule. If the stress level of the incremental adaptation schedule is excessively high, the incidence of motion sickness will force the termination of the adaptation. Although the relationship between adaptation and motion sickness is not well understood, it is possible, using sufficiently small increments in rpm to achieve adaptation without overt symptoms of motion sickness.

Subsequent experience with incremental adaptation (4) has shown that this acquired adaptation has two components. The first to occur is a direction specific adaptation which decays in hours after the cessation of rotation. This direction specific adaptation provides increased tolerance to rotation only in the direction employed in the incremental adaptation schedule. It is also associated with a reduced tolerance to head movements at zero velocity and an even lower tolerance to head movements performed with rotation in the opposite direction. The rather rapid decay of the direction specific adaptation reveals a second component of adaptation which is not direction specific and decays slowly over days. This second component of adaptation is not associated with symptoms at zero velocity and does afford increased tolerance to head movements performed with rotation in the opposite direction. This second component of acquired adaptation is of practical interest since it decays slowly and is not stimulus specific.

A method of acquiring adaptation to unusual vestibular stimuli which is both persistent and not stimulus specific could be put to immediate practical use. Not infrequently, student aviators are dropped from flight training because of repeated episodes of severe air sickness. It is reasonable to assume that in their situation the stimulus level is so high that the prompt emergence of air sickness does not permit the occurrence of any significant adaptation. A similar situation may be created in the laboratory by repeatedly exposing the subject to a high angular velocity without the benefit of incremental adaptation. To test the practical usefulness of this phenomenon, it was decided to determine whether laboratory conducted incremental adaptation could be beneficial to student aviators with a history of severe air sickness.

MATERIALS AND METHODS

Subjects for this experiment were two flight students who were dropped from flight training due to repeated episodes of severe air sickness. Both students had a life long history of motion sickness. Other than the unusual history of motion sickness, medical examination revealed two young, healthy adult males, both highly motivated to remain in the flight program. By history and on the basis of their previous performance in the flight program, these two students demonstrated an incidence of air sickness far above average and one would expect a high susceptibility to motion sickness. This suspicion was confirmed in both studens where comprehensive vestibular testing revealed normal function with the exception of a very high susceptibility to motion sickness.

The rotating device used in this experiment is the Slow Rotation Room I (SRR) at the Naval Aerospace Reseach Laboratory in Pensacola, Florida. The experiment is conducted inside a windowless, air conditioned, circular room which is ten feet in diameter and seven feet high. This room is attached to a large, high mass centrifuge that is capable of very smooth rotation at angular velocities from one to thirty

revolutions per minute (rpm) (5).
By means of controlled vestibular stimulation each subject is well adapted to each increment of angular velocity. The rotation is provided by the SRR rotating at constant angular velocities. The vestibular stimulation consists of paced head movements. In this procedure the subject sits upright and upon command from a tape recorder he makes head movements to the left, right, forward and backwards. As shown in Figure 1, the angular displacement of the head movement is controlled by the placement of pads in each direction of the head movement at an angle of 45 degrees from the vertical. The subject moves his head in the desired direction until he lightly touches the appropriate pad. The commands from the tape recorder specify a given direction every four seconds with the command to return to the upright following the initial command by two seconds. With this arrangement, a discrete head movement is made every two seconds and at the end of 480 such head movements (16 minutes) the subject is given a three to five minute rest period during which he sits quietly with his head in the upright position. The incremental adaptation schedule will be designed on a daily basis by the authors with the objective of keeping the stress level as high as possible yet avoiding significant motion sickness. Measurements of the tumbling ("giant hand") illusion will be made at each new increment of angular velocity to estimate the intensity of the vestibular stimulation. The severity of motion sickness will be measured continually using a previously described grading system (2), which is summarized in Table 1. At the end of each daily rotation, head movements will be immediately conducted at zero velocity to assess the level of acquired direction specific adaptation. It has been proposed that the acquired adaptation which is not direction specific is continually overtaking yet always lagging behind the acquisition of direction specific adaptation (4). If a subject performs sufficient head movements at a given angular velocity, he can then continue his head movements at zero velocity without any incidence of motion sickness. This occurs, presumably, because he has continued his adaptation to the rotating environment for a period of time long enough to permit the decay of the more transient direction specific adaptation to occur, even as he is rotating. If the stress level is properly adjusted, the subject will display minimal illusions at each new increment in angular velocity and will transiently develop no more than one or two motion sickness points throughout rotation. At the conclusion of rotations the subject should remain essentially asymptomatic during the head movements at zero velocity. If the stress level is excessive the illusions will be more prominent, the motion sickness more severe, and the postrun head movements will elicit frank motion sickness. Each subject began at one rpm and worked his way to ten rpm as quickly as possible.

RESULTS

The first attempt at adaptation was conducted with Subject 1, whose motion sickness susceptibility was somewhat lower than that of Subject 2. These results are displayed in Table 2. This first experiment was conducted over a seven day period and involved rotation on six days. Rotation was always in the counterclockwise (CCW) direction.

On the first day Subject 1 reached 5 rpm and experienced no motion sickness throughout the day. The subject executed a total of 7200 discrete head movements. This corresponds to exactly 4.0 hours making head movements and was accomplished in 6.18 hours of rotation. Illusions were not prominent at each new increment in angular velocity. Due to a technical oversight, no postrun head movements were performed on this first day.

On the second day the subject reached 6 rpm and developed no more than 1 motion sickness point while rotating. He performed a total of 5760 head movements (3.2 hours) in 6.85 hours of rotation. Illusions were clearly present at first reaching 5 and 6 rpm. After stopping the subject developed 5 motion sickness points in 115 head movements.

On the third day the subject reached 8 rpm and displayed no more than 2 motion sickness points but remained at 1 point throughout most of the day. He performed 6240 head movements (3.47 hours) in 7.30 hours of rotation. Illusions were present but not prominent. During the postrun head movements the subject developed 6 motion sickness points in 90 head movements.

On the fourth day the subject did not exceed 8 rpm. He developed a maximum of 3 motion sickness points and displayed 2 points for much of the day. He performed 4320 head movements (2.4 hours) in 7.0 hours of rotation. Illusions were present but not prominent at 6-8 rpm. Upon stopping the subject developed 4 motion sickness points in 120 head movements.

On the fifth day the subject reached 10 rpm. He displayed a maximum of 2 motion sickness points at any time during rotation and was asymptomatic at 10 rpm. The subject executed a total of 6720 head movements (3.73 hours) in 8.05 hours of rotation. Illusions were detectable but not prominent. Upon stopping the subject developed only 2 motion sickness points in 120 head movements.

On the sixth day the subject spent most his time at 10 rpm. He displayed a maximum of 2 motion sickness points and was asymptomatic by the end of the day. The subject executed 3360 head movements (1.87 hours) in 4.57 hours of rotation. Illusions were present but not prominent. Upon the cessation of rotation the subject developed 3 motion sickness points in 120 head movements.

On the seventh and eighth days the subject was flown in an aircraft especially prepared for studying air sickness. The subject displayed normal susceptibility which was intrepretéd as a significant improvement in his condition. Of the various maneuvers employed, the subject was most sensitive to "porpoising" which involved a few seconds of weightlessness. Several days later he participated in studies involving zero g parabolas of 30-45 seconds duration. Here he displayed such high air sickness susceptibility as to indicate that the incremental adaptation had afforded little protection for this particular type of maneuver.

Following the first incremental adaptation, periodic measurements of motion sickness susceptibility were made to estimate the rate of decay of the acquired adaptation. All of these tests were performed in the CCW direction, the same as that of the first incremental adaptation. At 12 days after the completion of the first study, there was minimal decay in the acquired adaptation. At 33 days there was significant decay and at 58 days the subject has returned to his previous baseline susceptibility.

Dissatisfaction with the incidence of motion sickness in the first incremental adaptation led to the decision to attempt a second, similar experiment. The objective was to examine the effects of lowering the stress level of the incremental adaptation schedule so as to reduce the incidence of illusions and motion sickness while rotating. This in turn would hopefully reduce the incidence of motion sickness caused by the postrun head movements. In this design the daily head movements always started at 1 rpm. This second CCW incremental adaptation was started 80 days after the completion of the first.

On the first day Subject 1 reached 3 rpm and was essentially asymptomatic throughout the day. He performed 3840 head movements (2.13 hours) in 3.50 hours of rotation. Illusions were not noted. Upon the cessation of rotation, the subject developed only 1 motion sickness point in 240 head movements.

On the second day the subject reached 4 rpm and briefly displayed 2 motion sickness points upon initially reaching 4 rpm. He performed 3240 head movements (1.8 hours) in 3.2 hours of rotation. Illusions were not detected. Upon stopping the subject remained asymptomatic through 240 head movements.

On the third day the subject reached 5 rpm and briefly displayed a single motion sickness point at 1 rpm. He performed 2760 head movements (1.53 hours) in 2.4 hours of rotation. Illusions were not reported. After stopping the subject remained asymptomatic during 240 head movements.

On the fourth day the subject reached 6 rpm. He remained essentially asymptomatic but transiently developed 2 motion sickness points after a momentary power failure. The subject executed 2760 head movements (1.53 hours) in 2.4 hours of rotation. Illusions were not reported. Upon stopping the subject developed a single motion sickness point in 240 head movements.

On the fifth day the subject reached 8 rpm. He was intermittently symptomatic, displaying one or two points for much of the day. The subject executed 4920 head movements (2.73 hours) in 3.95 hours of rotation. Illusions were not noted. Upon halting the subject developed 2 motion sickness points in 240 head movements.

On the sixth day the subject did not exceed 8 rpm and remained asymptomatic throughout rotation. He performed 2760 head movements (1.53 hours) in 2.5 hours of rotation. Illusions were not noted. Upon stopping the subject developed 3 motion sickness points in 240 head movements.

On the seventh day the subject reached 9 rpm and intermittently scored 2 motion sickness points on two occasions during the day. He performed 3240 head movements (1.8 hours) in 2.85 hours of rotation. Illusions were not noted. Upon the cessation of rotation the subject displayed 2 motion sickness points in 240 head movements.

On the eighth day the subject reached 10 rpm and he briefly displayed 2 motion sickness points upon initially 10 rpm. He performed 5760 head movements (3.2 hours) in 4.3 hours of rotation. Illusions were absent. Upon stopping the subject remained asymptomatic in 240 head movements.

Although the second incremental adaptation employed slightly fewer head movements than the first, the successful adaptation to 10 rpm was accomplished with less motion sickness and a much lower incidence of illusions. Provocative tests to assess motion sickness susceptibility (6) were conducted at 7 and 8 days after the completion of the second incremental adaptation. When compared to the earlier baselines before both adaptation experiments, there was a substantial reduction in motion sickness susceptibility. When this test was conducted in the direction opposite to that of both incremental adaptations, i.e. clockwise, there was no evidence of transfer of adaptation to the opposite direction. This result was surprising since some transfer was expected. To examine this possibility in more detail, it was decided to conduct a clockwise (CW) incremental adaptation.

Subject 1 started a CW incremental adaptation 14 days after the conclusion of the second CCW adaptation experiment. The technique was to be the same as the second CCW experiment and the goal would be 10 rpm CW.

On the first day the subject reached a surprising 6 rpm and displayed a maximum of 2 motion sickness points during the day. He performed 5760 head movements (3.2 hours) in 4.75 hours of rotation. Illusions were reported upon first reaching 5 rpm. Upon stopping the subject developed 2 motion sickness points in 240 head movements.

On the second day the subject reached 10 rpm. At one point he briefly developed 3 motion sickness points but was back to 1 point within an hour. He performed 5160 head movements (2.87 hours) in 4.45 hours of rotation. Illusions were not present. Upon stopping the subject developed 1 motion sickness point in 240 head movements. The subject's rapid progress to 10 rpm CW was most likely due to transferred adaptation from the second CCW experiment.

At this point the subject was returned to flight training but due to a recurrance of a chronic sinusitis, he did not immediately return to flying status. Because of some difficulty in controlling this chronic sinusitis, Subject 1 was temporarily suspended from flying. However the problem finally subsided and the subject finished flight training with little difficulty. He is presently in an operational flying billet and periodic follow-up has indicated no abnormal incidence of motion sickness. In the fall of 1975 Subject 1 briefly returned to Pensacola and it was possible to again measure his motion sickness susceptibility. At this time he displayed a typical (mild) endpoint at 17 rpm which is well above the average of 7-8 rpm.

The incremental adaptation of Subject 2 consists of a single, lengthy adaptation to 10 rpm CCW. Some difficulty was anticipated in that Subject 2 was found to be one of the most motion sickness susceptible individuals ever tested at the Naval Aerospace Medical Research Laboratory. The plan was essentially the same as employed with Subject 1. The results of this experiment are displayed in Table 3.

On the first day Subject 2 reached 4 rpm in 0.25 rpm increments. He was symptomatic almost the entire day, averaging about 3 motion sickness points and once reaching 8 points. He executed 9120 head movements (5.07 hours) in 9.5 hours of rotation. Illusions were always present and prominent above 3.25 rpm. Upon halting the subject developed 12 motion sickness points in 240 head movements. Although the stress level was intentionally designed to be low, it was still excessive for this highly susceptible subject.

On the second day the subject did not exceed 2.5 rpm. The subject was symptomatic much of the time and averaged 2 motion sickness points. He performed 7680 head movements (4.27 hours) in 8.7 hours of rotation. Illusions were prominent above 1.75 rpm. Upon halting the subject developed 6 motion sickness points in 240 head movements. Again the stress level was excessive.

On the third day the subject did not exceed 1.75 rpm. Throughout the day he did not develop more than 1 motion sickness point. He performed 4320 head movements (2.4 hours) in 3.25 hours of rotation. Illusions were less prominent than on the previous two days. Due to technical difficulties, postrun head movements were not conducted on this day.

In view of the unusually slow progress toward 10 rpm, it was decided to attempt the incremental adaptation with the use of an effective antimotion sickness drug, d-amphetamine sulfate (7,8).

On the fourth day the subject did not exceed 2 rpm. This run employed 10 mg d-amphetamine sulfate p.o. and the subject was asymptomatic throughout the day. He performed 5760 head movements (3.2 hours) in 5.4 hours of rotation. Illusions were present but not prominent. Upon stopping the subject remained asymptomatic in 240 head movements.

Using this technique the subject gradually worked his way to 7 rpm, reaching it on the sixteenth day. The subject generally averaged one or two motion sickness points however the trend was toward greater motion sickness at higher angular velocities. He performed approximately 4000-5000 head movements per day.

Illusions remained present and were occasionally prominent. Postrun head movements were associated with gradually increasing motion sickness scores, reaching 8 points on the sixteenth day. At this point the drug was combined with the technique of starting all daily head movements at 1 rpm.

From the seventeenth through the twenty-fourth day the subject gradually worked his way to 10 rpm. D-amphetamine sulfate and the technique of starting all daily head movements at 1 rpm were continued. The subject was continually symptomatic and averaged about 2 motion sickness points during each day. He performed about 3000 head movements per day. Illusions were almost always present but rarely prominent. The postrun head movements produced from 6-10 motion sickness points.

On the twenty-fifth day the subject again reached 10 rpm and no drug was employed for this run. The subject displayed only 1-2 motion sickness points throughout the day. He performed 1920 head movements (1.07 hours) in 2.4 hours of rotation. Illusions were present but not prominent at 10 rpm. Upon stopping the subject developed 7 motion sickness points in 180 head movements.

Subject 2 subsequently returned to flight training which he completed with no unusual difficulty with air sickness. He is presently in an operational flying billet and periodic follow-up has not revealed any abnormal incidence of air sickness.

DISCUSSION

On the basis of the results of this experimental probe and the reports of other investigators (10), it is altogether likely that the incremental adaptation to 10 rpm was beneficial to the two flight students. Firm conclusions are difficult to achieve with such a limited number of subjects. However, both subjects have long felt that the adaptation experiments were of considerable aid in completing their flight training. It is clear that established laboratory tests demonstrate that these two subjects were able to reduce their motion sickness susceptibility while associated with the Laboratory. The relationship between the reduced motion sickness susceptibility upon leaving the Laboratory and the subsequent success in flight training requires more careful examination.

If, for example, the same tests that were used to measure motion sickness susceptibility before and after adaptation could be continued through flight training, then one might gain some insight into the relationship between incremental adaptation and improved flight training performance. To obtain a better comparison, students with comparably high susceptibility might be paired, one receiving incremental adaptation and the other continuing in the flight program. It would also be useful to periodically measure the motion sickness susceptibility of normal students as they progress through training. It is probable that the motion sickness susceptibility of student aviators as a group decreases as they progress through training. This effect must be considered before estimating any improvement attributed to vestibular adaptation.

There are several aspects of the data which deserve additional comment. In the case of Subject 1, there was good transfer of laboratory acquired adaptation to flight maneuvers with the exception of those involving weightlessness. A possible explanation may lie in the fact that weightlessness exerts a major effect upon the otolith apparatus whereas the vestibular stimuli employed in the laboratory primarily condition the semicircular canals. Since one would not expect a conditioning process involving the canals to necessarily transfer to the otolith apparatus, it is then understandable that the incremental adaptation to 10 rpm afforded little protection against weightlessness.

After the second CCW incremental adaptation of Subject 1, a motion sickness susceptibility test failed to reveal any significant adaptation to the opposite direction. This was surprising in view of earlier work (9) which predicted substantial transfer. When a subsequent CW incremental adaptation was conducted, the rapidity of the subject's progress clearly implied considerable transfer from the previous adaptation in the opposite direction.The only explanation presently available is that this test was conducted prematurely, before the complete decay of the direction specific component of adaptation.

In the case of Subject 2, the facilitation of adaptation through the use of drugs represents an interesting possibility that requires further investigation. Whether d-amphetamine sulfate promotes adaptability by suppressing motion sickness cannot presently be proven. With Subject 2, the decision to employ a drug was largely based on the desire to continue the incremental adaptation. The initial response to the drug was significant but due to the subject's complaints of nervousness, the dosage was gradually lowered. What effect increased dosage would have had on the increased motion sickness symptomatology above 6 rpm is not known.

The practical value of incremental adaptation is that it provides a method of reducing air sickness susceptibility which, although time consuming, can be accomplished safely, simply, and inexpensively with a minimal investment in equipment. This method does not involve the elicitation of motion sickness. Although the data presented here were collected on a slowly rotating room, there is no reason why the technique could not be arranged to utilize a simple rotating chair.

From a theoretical viewpoint, incremental adaptation represents a flexible experimental technique for gaining insight into the process of vestibular adaptation. By regulating the direction of rotation, the angular velocity, and the number of head movements, the investigator can reliably generate a variety of vestibular stress levels that range from the subthreshold to those which are frankly provocative of motion sickness. The relationship between motion sickness and adaptation is not well understood. It has been reported that adaptation can occur without incurring significant motion sickness (3) and this has again been shown in these results. However very little is known about the circumstances promoting optimal adaptation. From existing data it seems probable that motion sickness is not a necessary element of adaptation. This still allows the possibility that motion sickness actually retards adaptation which would seem to explain the behavior of some student aviators. If this should be true then the present method of making decisions on the presence of early or mild motion sickness symptomatology may not prove to be very efficient. In the present design the presence or absence of the tumbling illusion was noted with the initial head movements at each new increment of angular velocity. Although this information can be generally related to the adaptation process it is not presently clear how it alone might be used to establish an incremental adaptation schedule.

In summary, two well motivated flight students with a life long history of motion sickness were referred to the Laboratory due to persistent air sickness of such severity as to jeopardize their continued participation in the flight program. By executing numerous paced head movements on a rotating room of gradually increasing velocity, both students substantially reduced their motion sickness susceptibility to the laboratory rotating environment. After developing an essentially asymptomatic tolerance to 10 rpm through the technique of incremental adaptation, they returned to the flight program. Both students completed flight training and are presently in operational flying billets where they have experienced no unusual incidence of motion sickness. In these two cases it was possible to employ a recently described adaptation to vestibular stimuli which permits the effective transfer of reduced motion sickness susceptibility from the laboratory rotating environment to an operational flight situation.

REFERENCES

1. Graybiel, A. Structural elements in the concept of motion sickness. Aerospace Med.40: 351-367, 1969.
2. Graybiel,A., C.D.Wood, E.F.Miller II, and D.B.Cramer. Diagnostic criteria for grading the severity of acute motion sickness. Aerospace Med.39: 453-455, 1968.
3. Graybiel, A., and C.D.Wood. Rapid vestibular adaptation in a rotating environment by means of controlled head movements. Aerospace Med.40: 638-643, 1969.
4. Graybiel, A., and J.Knepton. Direction-specific adaptation effects acquired in a slow rotation room. Aerospace Med.43: 1179-1189, 1972.
5. Hixon, W.C. Instrumentation for the Pensacola Centrifuge-Slow Rotation Room I Facility. NSAM-875. NASA R-37. Pensacola, Fla., Naval School of Aviation Medicine, 1963.
6. Kennedy, R.S., and A.Graybiel. The Dial Test: A standardized procedure for the experimental production of canal sickness symptomatology in a rotating environment. NSAM-930. NASA R-93. Pensacola, Fla., Naval School of Aviation Medicine, 1965.
7. Graybiel, A., C.D.Wood, J.Knepton, J.P.Hoche and G.F.Perkins. Human assay of antimotion sickness drugs. Aviat.Space Environ.Med.46(9): 1107-1118, 1975.
8. Wood, C.D., and A.Graybiel. Theory of antimotion sickness drug mechanisms. Aerospace Med.43: 249-252, 1972.
9. Reason, J.T., and A.Graybiel. Adaptation to Coriolis accelerations: its transfer to the opposite direction as a function of intervening activity at zero velocity. NAMI-1086. Pensacola, Fla., Naval Aerospace Medical Institute, 1969.
10. Dowd, P.J., and R.L. Cramer. Habituation transference in coriolis accelerations. Aerospace Med.38: 1103-1107, 1967.

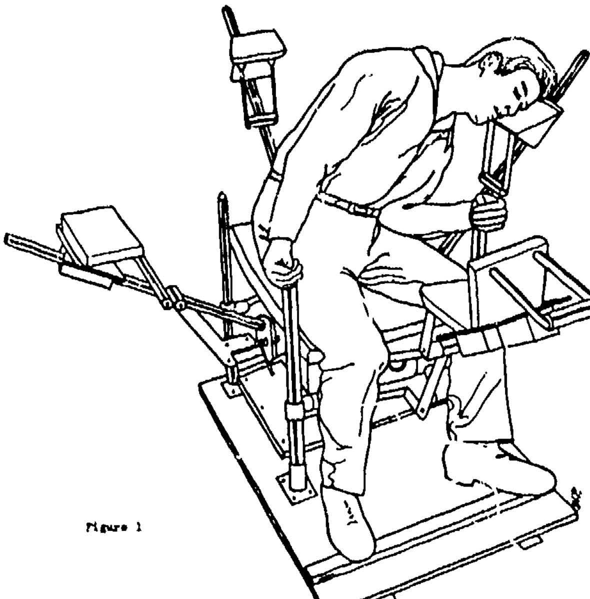

Figure 1

INCREMENTAL ADAPTATION — Subject 1

Date	Run Day	1	2	3	4	5	6	7	8	9	10	Daily Total	Average MS Score	Postrun SM	Postrun MS Score
		Angular Velocity (rpm)													
8 Jan '71	1 (CCW)	0.96*	0.96	1.92	1.92	1.44						7.20	0		
9	2					1.92	3.84					5.76	1	.12	3
10	3					0.48	0.96	3.84	0.96			6.24	1	0.09	6
11	4						0.48	0.96	2.88			4.32	2	0.12	4
13	5						0.48	0.48	0.48	3.84	1.44	6.72	1	0.12	2
14	6									0.96	2.40	3.36	1	0.12	3
		0.96	0.96	1.92	1.92	3.84	5.76	5.28	4.32	4.80	3.84			0.57	
												Grand Total: 34.17			
6 May '71	1 (CCW)	0.96	0.96	1.92								3.84	0	0.24	1
7	2	0.12	0.12	0.12	2.88							3.24	1	0.24	0
10	3	0.12	0.12	0.12	0.48	1.92						2.76	0	0.24	0
11	4	0.12	0.12	0.12	0.12	0.48	1.80					2.76	1	0.24	1
12	5	0.12	0.12	0.12	0.12	0.12	0.48	1.92	1.92			4.92	2	0.24	2
13	6	0.12	0.12	0.12	0.12	0.12	0.12	0.12	1.92			2.76	0	0.24	3
14	7	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.48	1.92		3.24	1	1.24	2
17	8	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.96	1.44	3.76	0	0.24	0
		1.80	1.80	2.76	3.96	2.88	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	
												Grand Total: 31.20			
1 June '71	1 (CW)	0.96	0.96	0.96	0.96	0.96	0.96					5.76	1	0.24	2
2	2	0.12	0.12	0.12	0.24	0.24	0.48	0.96	0.96	0.96	0.96	5.16	1	0.24	1
		1.08	1.08	1.08	1.20	1.20	1.44	0.96	0.96	0.96	0.96			0.48	
												Grand Total: 11.40			

* 1.00 = 1000 individual head movements, spaced at two second intervals

Table 2

Scoring Severity of Acute Motion Sickness

Category	16 points	8 points	4 points	2 points	1 point
Nausea syndrome	Vomiting or retching	Nausea* II, III	Nausea I	Epigastric discomfort	Epigastric awareness
Skin color		Pallor III	Pallor II	Pallor I	Flushing
Cold sweating		III	II	I	
Increased salivation		III	II	I	
Drowsiness		III	II	I	
Pain					Headache
Central nervous system					Dizziness: Eyes closed ≥ II; Eyes open III

*III = severe or marked, II = moderate, I = slight.

Table 1

INCREMENTAL ADAPTATION — Subject 2

Date	Run Day	1	2	3	4	5	6	7	8	9	10	Daily Total	Average MS Score	Postrun SM	Postrun MS Score
		Angular Velocity (rpm)													
31 Mar '71	1 (CCW)	1.92*	1.44	1.92	3.84							9.12	3	0.24	12
1 Apr	2	1.92	3.84	1.92								7.68	2	3.24	6
2	3	1.92	2.40									4.32	1		
5	4a	1.92	3.84									5.76	[illegible]	0.24	0
6	5a		2.88	0.96								3.84	0	0.24	0
7	6a		1.92	1.92								3.84	0	0.24	0
12	7b		0.96	2.88								3.84	0	0.24	2
13	8b			2.88	0.96							3.84	0	0.24	1
14	9b			0.96	2.88							3.84	0	0.24	1
15	10b				2.88	0.96						3.84	2	0.24	0
16	11b				1.92	1.92						3.84	0	0.24	1
19	12b				0.96	3.84						4.80	0	0.24	1
20	13b					1.92	2.88					4.80	1	0.24	3
21	14b						2.88	1.92				4.80	1	0.24	2
22	15c						0.48	0.48				0.96	[illegible]		
27	16b		0.48			0.48		2.88				3.84	2	3.24	7
28	17b	0.12	0.12	0.12	0.12	0.12	0.12	1.68	2.88			5.28	2	0.24	8
29	18b	0.12	0.12	0.12	0.12	0.12	0.24	0.48	1.20	0.96		3.48	2	0.24	7
3 May	19b	0.12	0.12	0.12	0.12	0.24	0.24	0.72	0.48	1.44		3.60	4	0.24	6
4	20b	0.12	0.12	0.12	0.12	0.24	0.24	0.24	0.48	2.16		3.84	3	0.10	10
5	21c	0.12	0.12	0.12	0.12	0.24	0.24	0.24	0.48	1.80		3.48	2	0.08	8
6	22c	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.36	0.96	2.88	2	0.21	6
7	23b	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.36	1.20	2.52	3	0.20	7
10	24c		0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.24	2.40	3.48	2	0.13	5
11	25	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.24	0.72	1.92	1	0.10	7
		8.16	18.96	14.52	14.52	10.56	7.80	9.12	6.00	6.96	5.28			5.08	
												Grand Total: 109.[illegible]			

* 1.00 = 1000 individual head movements, spaced at two second intervals
a 10 mg d-amphetamine sulfate, orally
b 5 " " " "
c 2.5 " " " "

Table 3

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