Vestibular Habituation with Gimbal Mounted Tumbling Device

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A prototype Gimbal Mounted Tumbling Device has been evaluated for its suitability as a vestibular habituation device. Twelve healthy males between 20-40 years of age were subjected to regular exercises on the Gimbal Mounted Tumbling Device for 12 & 16 minutes per day schedules, over five day period. The exercise comprised of manual rotation through 45°, 90° and 360° in roll, pitch and yaw planes. The habituation was studied by recording and comparing the post-rotatory nystagmus following stimulation of horizontal semi-circular canal in IAM modified Barany's rotation chair at 20 RPM, before and after the stoppage of exercise to assess the retention of habituation. Maximum velocity of the slow phase (MVSP) was used as parameter for the ENG evaluation, and a 20% reduction of response in post-exercise record was taken as indication of acquisition of habituation. Evidence of habituation was seen in 8 of the subjects (66.6%) and 2 of them retained at beyond 5 days. The mechanism of habituation and the possibilities regarding the uses of the device are discussed.

SPATIAL disorientation is among the most important problems challenging aviation medicine. Air sickness is another such nagging problem. It is well known that both spatial disorientation and air sickness are often the result of over stimulation or in-appropriate stimulation of the vestibular system giving rise to in-appropriate sensations. Controlling the sensitivity of the vestibular system is therefore a logical approach to reducing a pilot's susceptibility to spatial disorientation and air sickness. It has been observed that when a subject is exposed to repeated rotary stimulation there is progressive reduction of the response by the vestibular system. This response decline is called habituation. It is a complex phenomenon characterised by:—

(a) 'Acquisition, which is decline of response on repeated stimulation,
(b) 'Retention', which is the retention of such response decline over a period of time, and
(c) 'Transfer', which implies habituation to one direction of rotation producing equal or near equal response decline in opposite direction.

Vestibular habituation is one of the important preventive measures advocated for controlling a pilot's susceptibility to spatial disorientation and air sickness.

A degree of vestibular habituation occurs naturally in the course of flying training when a trainee pilot is repeatedly exposed to aircraft manoeuvres stimulating the vestibular system[1,3]. Thus, an experienced pilot is habituated depending on his level of experience and is certainly less susceptible to spatial disorientation. Such habituation has to be maintained by regular flying since dehabituation sets in with lack of current flying practice. Maintaining current flying practice involves many practical problems. A ground based facility for imparting vestibular habituation appropriate to the needs of flying is therefore ideal. It will be particularly useful to trainee pilots and the serving pilots who are resuming flying after a gap. The requirements of an ideal habituation device are:-

(a) capacity to rotate in all the planes around the subject,

(b) rate of rotation should be easily and accurately controllable by the subject and should cover a wide range,

(c) operation should be simple and under full control of the subject.

(d) a few minutes of exercise in a day should be adequate.

Vestibular trainining programmes using various types of vestibular habituation techniques and devices have come into use by the different Air Forces[10]. Mostly gymnastic type of devices are being used for this purpose. The 13th Air Force Research Advisory Panel recommended development of a Gimbal Mounted Tumbling Device (GMT device) for use as a vestibular habituation device by the Flight Cadets and Pilots of IAF. A prototype GMT device has been made by ABEU, Bangalore. We have carried out an assessment of this device at the Dept of Otolaryngology, IAM Bangalore, prior to its introduction in IAF and our findings are presented in this paper.

Aim

Aim of this study is to assess the capability of the DMT device to effect vestibular habituation.

Description of the Gimbal Mounted Tumbling Device

The GMT device essentially consists of a set of three metallic rings mounted on gimbals so that they can freely rotate through a full circle around an axis passing through the respective sets of gimbals. The outer most ring is mounted on a fixed base and rotates around a vertical axis. The middle ring is mounted on the outer and rotates around a lateral horizontal axis. The inner ring is mounted on the middle one and rotates around an anteroposterior axis. A seat is mounted at the centre of the rings attached to the inner ring.

The operation of the device is fully manual and simple. The subject is strapped in his seat. He grips the two handle bars above the level of his head. The feet rest on a horizontal foot rest in front. He can perform rolling, pitching and yawing movements by rotating the inner middle and outer rings respectively. The rate, degree of rotation and cessation of manoeuvres is all controlled by the subject himself. There is freedom of rotation through 360° in each plane and in all the planes at a time. Figures 1-6 show the device in different attitudes.

Materials and Method

Electronystagmography (ENG) is the best available objective method for study of vestibular habituation and the same was employed for the present study. It is not practicable to carry out any nystagmography with a subject in GMT device. Hence a motorised Barany's Rotation Chair with facility for recording of nystagmus was utilised. Murty *et al*[9] have established the suitability of this chair for vestitular habituation studies by recording post-rotatory nystagmus.

Twelve asymptomatic healthy males between 25 to 40 years of age were the subjects for study and six such individuals acted as controls. They were members of IAM staff and trainees and there were no aircrew among them. A brief clinical history was taken from and careful clinical examination carried out on all subjects and controls with a view to exclude those with any otological, vestibular and systemic organic disorder.

A baseline record of post-rotatory nystagmic response of each subject and control was carried out after subjecting him to 10 rotations in 30 seconds (20 RPM) followed by stop within one second. A record of spontaneous nystagmus, if any, was obtained in all individuals with eyes open and closed, before subjecting them to rotation. Calibration

Fig. 1—*Subject seated in GMTD—Normal attitude*

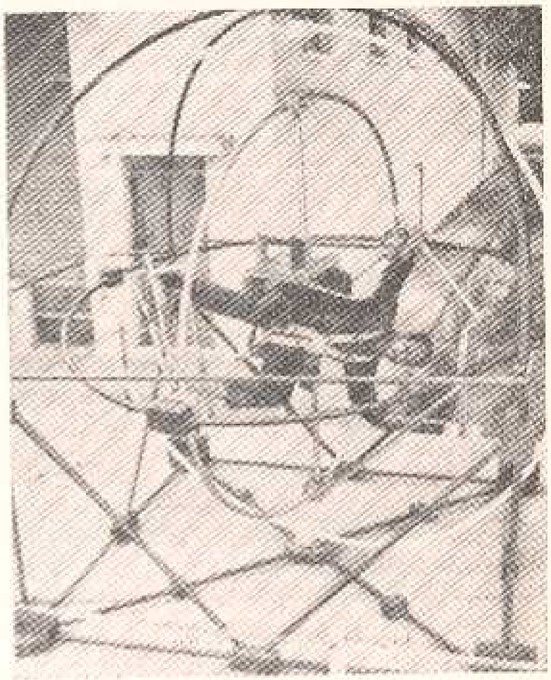

Fig. 2—*45° Roll to left*

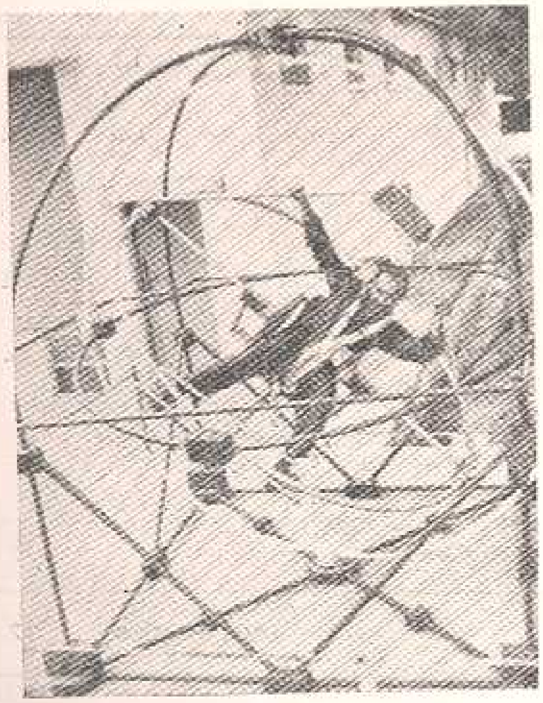

Fig. 3—*90° Roll to left*

Fig. 4—*45° Pitch down*

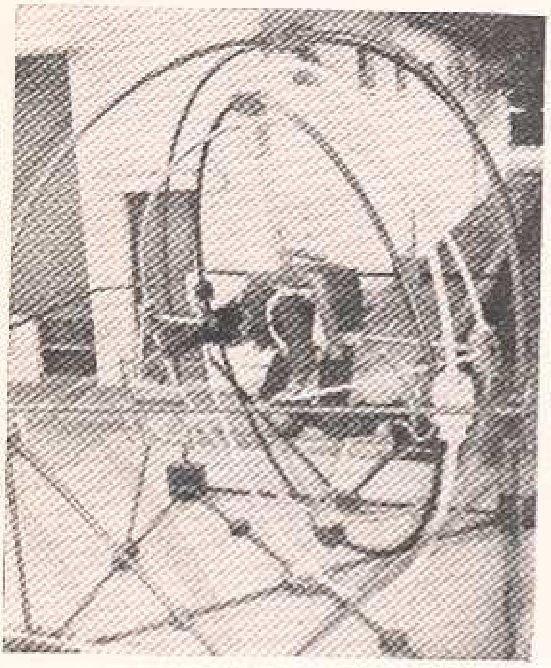

Fig. 5—*90° Pitch down*

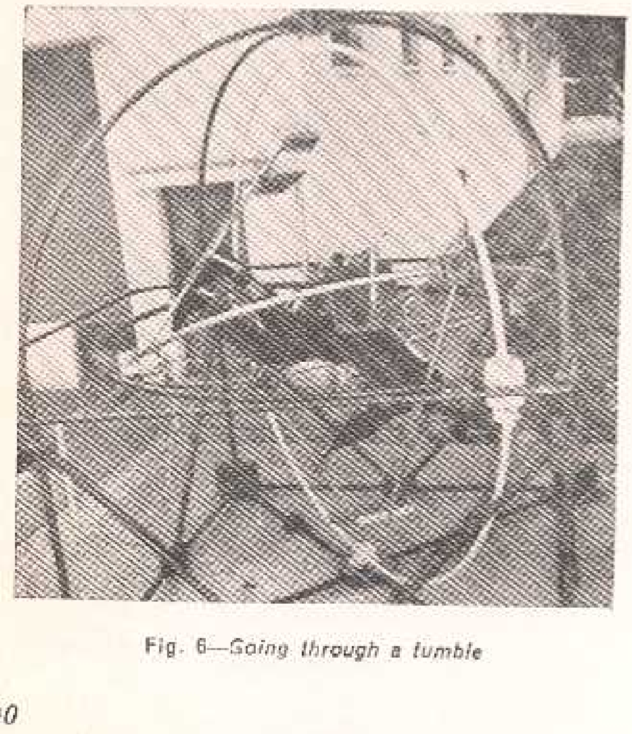

Fig. 6—*Going through a tumble*

of eye ball movements was carried out before and after each record. Only horizontal nystagmus was recorded with head bent 30° forward during rotation and eyes closed the rotation was given initially in clockwise (CW) direction followed by counter clockwise direction (CCW) with an interval of 5 min between the rotations. All the subjects and controls were advised to avoid any drugs or alcohol for 24 hours prior to the ENG recording. The ENG response was evaluated by calculating the maximum velocity of slow phase of nystagmus (MVSP) for ten typical beats evenly distributed over a 10 sec period of maximum activity. The latency of nystagmus, if any, was also noted.

Acquisition:—To assess the acquisition of habituation with GMT device all members of the subject group were given daily exercise on GMT device for five consecutive days, followed by recording of ENG responses in the same manner as the baseline record. The first seven subjects were given exercise for 12 min daily as per the schedule shown in Table I

Table-I
12 Minutes Exercise Schedule

Movement	No of repetitions (per min)	Duration (min)
(a) 45° rolling to right and left alternately.	12	2
(b) 45° pitching up and down alternately.	12	2
(c) 90° rolling to right and left alternately.	8	2
(d) 90° pitching up and down alternately.	8	2
(e) Horizontal rotations (yawing) to right and left.	6	2
(f) Combined movements in all planes including tumbling through 360° in roll and pitch planes.		2
Total duration		12

Two of these subjects (Nos 6 & 7) showed no evidence of habituation on completion of the five day exercise and were given further exercise for five days in the following week after a gap of two days. The last five subjects were given exercise for 16 min per day according to a modified schedule (Table II).

Table-II

16 minutes Exercise Schedule

Movement	No of repetitions (per min)	Duration (min)
(a) 45° rolling to right and left alternately.	12	1
(b) 45° pitching up and down alternately.	12	1
(c) 90° rolling to right and left alternately.	8	4
(d) 90° pitching up and down alternately.	8	4
(e) Tumbling through 360° in roll plane.	2	1
(f) Tumbling through 360° in pitch plane.	2	1
(g) Horizonal rotations (yawing) to right and left.	6	2
(h) Combined movements in all planes and directions.		2
	Total duration	16

The control group was not required to do any form of exercise and were allowed their normal activities. After a gap of five days their ENG records were repeated.

Retention : To determine the retention of habituation in the subject group, they were allowed a rest period of five days on completion of exercise schedule and their ENG responses were recorded under same conditions as during baseline and post-exercise records. Only seven subjects were available for the retention ENG study. In three of them recording was made after 6 days and one after 8 days due to practical difficulties. These subjects carried out their normal activities during the gap period.

Results

The post-rotatory ENG responses of all subjects and controls obtained before exercise, after exercise and after the rest period were compared for the mean value of response to the CW and CCW rotations. Reduction of MVSP in the post-exercise records indicated acquisition of habituation and a persistence of the reduction after the period of rest, indicated retention of habituation. Figure 7 shows a typical response of habituation in subject No 12. A variation of ENG response of a subject upto 20% is generally regarded as within normal limits. A response decline of 20% or more has been regarded as significant and indicative of habituation.

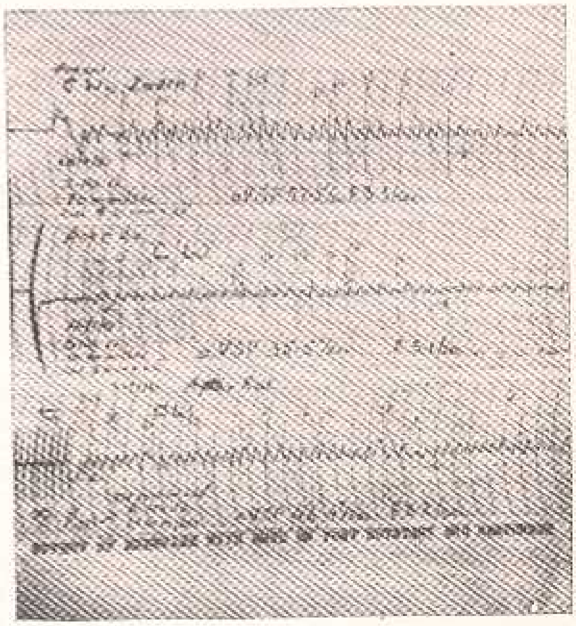

Fig. 7—*A typical response of habituation in a subject*

In the subject group who underwent 12 min exercise/day, 6 out of 7 subjects have shown response decline ranging from -11.2% to -53.8% (Table III) and in 5 of them it is indicative of acquisition of habituation, being well over 20%. One subject showed a marginal (2.9%) increase of response which is not significant. Table IV shows the response of those given 16 min a day exercise. The exercise schedule has affected a definite response decline ranging from-18.3% to 48.8% in all the 5 subjects and was of significant level on 3 of them.

The responses of controls are shown in Table V at baseline level and after an interval of five days. Four of them have shown no significant change in response. The remaining two, i.e., subject Nos 2 and 3, have shown increased response of 20.5% and 49 0% respectively. This could be due to apprehension and attempts at visual fixation during baseline recording leading to suppressed response.

Table—III

Post-rotatory ENG responses of seven subjects exposed to 12 minutes/day exercise schedule

Subject No.	Baseline MVSP (°/Sec)	Post exercise MVSP (°/Sec)	Percentage change in response
1	49.9	30.8	—38.4
2	39.4	18.5	—53.0
3	17.3	17.8	+2.3
4	32.8	15.4	—32.3
5	16.5	14.7	—11.2
6	62.0	28 2	—53.8
7	29.7	19.2	—35.2
		Mean (—) (P< 0.05)	31.6

MVSP — Maximum velocity of slow phase.

Table—IV

Post-rotatory ENG responses of five subjects exposed to 16 minutes/day exercise schedule

Subject No.	Base line MVSP °/Sec	Post exercise MVSP °/Sec	% change in response
8	37.6	20.0	—46.8
9	44.5	36.3	—18.3
10	35.0	28.3	—10.3
11	35.0	24.3	—30.6
12	49.1	33.7	—31.4
		Mean (—) (P <0.01)	29.3

Table—V

Post rotatory ENG responses of controls

Subject No.	Base line MVSP °/Sec	After five days MVSP °/Sec	% change in response
1	32.3	34.0	+5.3
2	26.3	31.7	+20.5
3	20.1	30.0	+49.0
4	33.3	27.4	—17.7
5	40.9	45.3	—3.4
6	38.2	39.2	+2.8
		Mean (+) (NS)	9.4

Table—VI

Retention of habituation in seven subjects after stoppage of exercises

Subject No.	Rest period in days	ENG response MVSP o/Sec	% change due to exercise	% change after rest retained
1	6	40.6	—38.4	—18.7
2	5	37.3	—53.0	—5.3
3	5	28.3	—46.8	—24.7
9	8	41.0	—18.3	—7.9
10	5	36.9	—19.3	+5.4
11	6	33.6	—30.6	—3.8
12	6	34.6	—31.4	—29.6
			Mean (—) (P <0.05)	12.1

Table—VII

Summary of results indicating acquisition and retention of habituation

All values represent percentage change over baseline value of MVSP.

	Controls (N=6)	Subjects (N=12) Acquisition	Retention
Mean change in response	+9.4	—30.5	—12.1
Range	—16.0 to +53.3	—58.2 to +7.8	—29.6 to +11.2
Over 20% change in response	2 increase	8 decrease	2 decrease

Retention of habituation was studied in 7 of the subjects, of whom 6 have shown the persistence of response decline which is also statistically significant. In 2 of these subjects over 20% response decline was found persisting. Retention of habituation depends on the intensity and duration of stimulus for habituation. It is already proved by animal and human experiments that vestibular habituation is retained normally for a few days or weeks. Our results are consistent with these observations.

Table VII shows a summary of the results. The subject group has shown a change in response ranging from +7.8% to −58.2% with a mean of −30.5%. A total of 8 or two thirds of the subjects have shown over 20% response decline which has been regarded as indicative of acquisition of habituation. On the contrary the controls have tended to show increased response, range −16.0% to +53.3% with a mean of +9.4%. In two of them the increase was over 20%. The trend for retention of the response decline is also obvious.

Discussion

The results have shown adequate evidence of habituation in the subject group. Most of the studies of vestibular habituation have reported about 30% response decline[1,9] and our results are in close agreement. It is generally accepted that maximum habituation is specific to the stimulus and is only partially transferred to the direction or plane of rotation other than that of the stimulus. Most workers have studied vestibular habituation by employing a rotation chair for effecting vestibular habituation, which is assessed after giving a stimulus identical to the stimulus used for habituation. In the case of the GMT device the stimulus is neither precisely controllable nor a direct recording of response possible. The stimulation by GMT device is essentially a voluntary, oscillatory rotation in three axes with no post-rotatory phase. It is neither practicable nor essential to maintain any specificity of the stimulus. The assessment of habituation has been done indirectly by measuring the post-rotatory nystagmus on a standard rotation chair, which actually indicates the overall effect of the habituation on the sensitivity to rotational stimulation in horizontal plane. Such methodology has been employed by Collins[2] in his study of vestibular habituation in figure skators.

The exercise schedule lays greater stress on rotation in roll and pitch planes, i.e, around the horizontal axis whereas the evaluation of response was done by rotation around vertical axis. Guedry[4] in his study on normal human subjects has observed that the subjective phenomenon and nystagmus is more marked in horizontal axis rotations as compared to vertical axis. Thus the evidence of response decline to vertical axis rotation in our subjects indicates that, besides acquisition, a transfer of habituation is also achieved.

Comparison of the effectiveness of the two exercise schedules shows that the subjects, who had 12 min/day exercise had a mean response decline of 31.6 against 29.3% in subjects who had 16 min daily exercise. This suggests that the 16 min schedule did not offer any additional advantage. This aspect, however, requires further investigation on a larger subject group.

As regards the parameter employed for the evaluation of the ENG response the MVSP was found to be most consistent as noted by other workers[3,7,11]. The frequency of nystagmus was tried out as a parameter but the results were inconsistent and hence discontinued.

The mechanism of vestibular habituation is not clear so far. Howard and Templeton[6] have discussed 5 possible explanations which are examined below in the context of the habituation by GMT device :-

(a) Role of peripheral factors—The reduction of the sensitivity of the peripheral sense organ by a central process via the efferent nerve fibres to labyrinth has been suggested but there is no direct evidence supporting the possibility.

(b) Nystagmus dysrhythmia—Some workers have observed nystagmus dysrhythmia or labyrinthine fibrillation response in post habituation ENG records with reduction of duration of nystagmus. We have not observed any such dysrhythmia or any consistent reduction of duration of nystagmus.

(c) Effect of arousal—It has been suggested that vestibular habituation could be due to a general loss of arousal activity in brainstem nuclei consequent upon the declining arousal value of the repeated rotation. Lowered arousal cannot be a factor in producing habituation to rotation in GMT Device since the arousal level during rotation could not have obviously influenced the response decline observed. using a different stimulus hours after the habituation stimulus ceased.

(d) Effect of directional balance mechanism—It has been suggested that the amount of habituation in the direction of rotation depends on the ratio of duration of rotation to the rest interval, before rotation in opposing directions starts. Our subjects mainly carried out oscillatory movement in both directions of rotation with virtually no rest interval before the commencement of rotation in opposing direction. Hence the directional balance mechanism does not appear to be applicable.

(e) Habituation and learning—The most commonly accepted view is that vestibular habituation is akin to learning, under the influence of central adaptive processes. In the presence of the conflicting vestibular sensory input during post-rotatory nystagmus learning probably leads to greater weighting of visual imformation or if the eyes are closed, of the proprioceptive information with consequent reduction of nystagmus and associated symptoms. Learning remains the most likely mechanism of vestibular habituation with GMT Devices.

The GMT Device offers an added benefit to the student pilots by giving them the feel of different unusual attitudes of the body experienced in flying. The subject can repeatedly experience the banked, inverted, turning, rolling and diving attitudes with corresponding bodily sensations. Prior experience and some habituation to these attitudes can be ve helpful to the student pilot in overcoming t anxiety and discomfort associated with such attitu of body, during the early flying training.

The utility of a vestibular habituation device ca be ascertained only if it is regularly and routinely use by a large pilot population. Thus the device shoul not merely impart habituation but be necessaril acceptable to the pilots. In this respect the GMT has the following advantages :-

(a) The simple design ensures its serviceabilit all the time.

(b) About 12 min of exercise at any convenien time of the day will be adequate.

(c) It can provide a moderate amount of physical exercise as well as recreation and can thus contribute to maintenance of aircrew health.

(d) It can particularly be useful to student pilots to familiarise with the feel of the seat and harness system in different unusual attitudes, before commencing flying training.

Conclusions

Our preliminary assessment of habituation produced by GMT Device in the subject group following 6 days of short duration training has confirmed the usefulness of the device. Further trials on aircrew population are needed to work-out the most convenient exercise schedules required to maintain sustained habituation level.

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