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TITLE

PSEUDO-CORIOLIS EFFECTS IN SCREENING FOR SIMULATOR SICKNESS

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Pseudo-Coriolis Effects in Screening

for Simulator Sickness

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Final Report - April 30/96

Walter H. Johnson,PhD., FCASI, FAsMA
Department of Otolaryngology
St. Michael's Hospital, Toronto, Ontario
and
F.A. Sunahara, PhD.
Department of Pharmacology
University of Toronto

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Part I

IMPORTANCE OF THE NON-AUDITORY RECEPTORS OF THE INNER EAR IN VISUALLY INDUCED NAUSEA AND SELF-VECTION

INTRODUCTION

The importance of the non-auditory labyrinths of the inner ear as the principal sensory receptors responsible for motion sickness has been well established (6). Head movements are especially provocative when superimposed upon body or vehicle movements in such a manner as to result in cross-coupled angular accelerations (Coriolis effects) as we have previously demonstrated (3,7). Although nausea and disorientation can also develop from head movements concomitant with a moving visual field but with the body stationary (pseudo-Coriolis effects) (2), the relative importance of the inner ear in such circumstances is not fully understood. It was the objective of this study to clarify this question by exposing both normal and labyrinthine defective volunteer subjects to pseudo-Coriolis stimulation and compare the sensory effects thereby produced.

METHODS

The subjects sat in a specially constructed arm-chair within a circular dark room. Moving spots of white light were projected on to the entire wall facing the subject as reflected from a rotating assembly of mirrors on the ceiling (Fig. 1). A variable speed electric motor controlled the rate of horizontal movement of the light spots which was maintained at 10 r.p.m. A total of 39 subjects were tested. Of these, 15 were normal healthy subjects with no history of vestibular disorders, 18 had undergone unilateral labyrinthectomies, while 6 had non-functioning labyrinths due to bilateral labyrinthectomies (an extremely rare condition). Al labyrinthine defectives had labyrinthectomies due to acoustic neuromas with no other neurological defects. The labyrinthectomies resulted in complete deafness and complete absence of response to cold water irrigation on the side or sides of the head involved thus establishing complete absence of vestibular receptors on the side or sides involved. Male and female subjects aged 25 to 70 were used in this series.

When the stationary subject, seated centrally inside the room, (Fig.1) viewed the rotating visual field, a sensation of self-rotation (vection) in the opposite direction was always experienced. Times for onset of self-vection and degree of subjective intensities were determined verbally by intercom. Pseudo-Coriolis effects resulted from controlled patterns of nodding head movements concomitant with sensations of self-vection. The head nodding movements at a velocity of 5^0/s for 6s were standardized by means of an electrically driven head rest with pads held in position by means of Velcro straps around the forehead. A small D.C. electric motor actuated nodding head movements through an arc of 30^0. Nodding movements at this time induced an increased sensation of spatial disorientation often accompanied by nausea. The test procedure was divided into six phases (numbered 1 to 6) each lasting for five minutes. The activity involved in each phase was as follows:

Phase 1. Control period. Light spots stationary. Head stationary.

Phase 2. Light spots moving. Head stationary.

Phase 3. Light spots moving. Intermittent nodding head movement.

Phase 4. Light spots moving. Continuous nodding head movement.

Phase 5. Light spots moving. Head stationary.

Phase 6. Light spots stationary. Head stationary.

The intensity of discomfort was assessed using a modified Grabiel's Index (GI) (5), (0 = no symptoms; 1 = slight dizziness & disorientation; 2 = slight gastrointestinal discomfort, sweatiness; 3 = nausea; 4 = severe nausea; 5 = request termination because of nausea; 6 = emesis imminent.)

The subjects were strapped upright in the arm-chair at the center of the room. After appropriate instrumentation was completed the subject was allowed to stabilize. They were instructed to keep the eyes open throughout. Two patterns of head movement were used as follows; the first head movements were of a square wave pattern at 6-s intervals followed by a second series consisting of continuous head movements (Fig.2). The experiment was terminated when the entire cycle was completed or when the subject complained of severe nausea (Graybiel's Index = 5); the head movement was stopped and the subject was requested to close his/her eyes.

Three types of subjects were used:

Normals with no history of vestibular disease (Group A).

Subjects with unilateral vestibular function only (Group B).

Subjects with bilateral non-functional labyrinths (Group C - Eighth cranial nerve sections for bilateral acoustic neuroma).

In Groups A and B, the subjects were requested to respond verbally through an intercom system to questions at regular intervals regarding symptoms (self-vection, headache, perspiration, nausea, etc.) Group C subjects were completely deaf and had been instructed in writing to announce verbally if any symptoms were experienced throughout all phases of the experiment.

All subjects were fully informed in advance of the possible discomfort and signed hospital's approved consent forms.

Analysis of variance was carried out on the data.

RESULTS

There were no consistent or significant changes in blood pressure nor heart rate during pseudo-Coriolis stimulation as was previously reported for normal healthy subjects (4).

The findings indicate no significant differences in the degree of nausea from pseudo-Coriolis stimulation among the unilateral and bilateral subjects compared to the normal subjects (Table 1). In the 15 normal subjects, 27% exhibited no symptoms of motion sickness, while the remainder (73%) developed symptoms ranging from 1 to 4^+ on the GI Scale. Of the 18 unilateral defective subjects, 56% showed symptoms of motion sickness ranging from 1 to 4^+ in GI. Of the six bilateral defective subjects, (67%) developed some degree of motion sickness ranging from 1 to 3 on the GI Scale. It is interesting to note that in unilateral & bilateral categories, 83% of the series had GI of 2 or less whereas the 67% of the normal subjects had GI of 2 or less. These findings are of particular significance in establishing that motion sickness can indeed be induced in both unilateral and bilateral defective subjects in certain circumstances (moving visual field concomitant with head movement in a different spatial plane and with eyes open).

When the subjects were exposed to the moving visual field only (no head movement), pronounced self-vection occurred in all subjects but sometimes with earlier onset in the bilateral detective subjects as compared to normal and unilateral defective subjects (Table 2). The descriptions of the subjective intensity of the self-vection reported in labyrinthine defective subjects were much more pronounced than when described by normal subjects. The times for onsets of self-vection however, were independent of the degree of nausea.

CONCLUSIONS

It was established by this study that nausea and self vection induced by pseudo-Coriolis stimulation (subject stationary with head movements concomitant with a moving visual field) can develop not only in normal health subjects but also in both unilateral and bilateral labyrinthectomized subjects. The observation that the intensity of subjective self-vection was more pronounced in the labyrinthine defective subjects would suggest that the vestibular receptors in normal subjects may modulate induced self-vection. It has been well established by several authors that motion sickness as the term is generally used (sea sickness, air sickness) does not occur in labyrinthine defective (LD) subjects (6) and when present it is due to conflicting sensory inputs. It may be considered surprising, therefore, to find that nausea developed in our LD when exposed to pseudo-Coriolis stimulation. However, it should be pointed out that even LD subjects were also exposed to conflicting sensory input in that our experimental conditions produced conflict of visual sensory input (horizontal subjective self-vection superimposed on vertical visual eye movements). In this regard, it was recently established by Cheung et al, (1) that no visually induced sickness occurred in any of their six bilaterally defectives subjects who were seated in a chair, the head immobilized, and exposed to a moving visual field. Normal subjects with health vestibular responses, however, did suffer nausea of varying intensity when exposed to the same conditions. Our findings therefore are of particular significance in that nausea can indeed be induced in subjects having little or no vestibular component when exposed to a moving visual field concomit with head movement which causes conflict of visual input (horizontal self-vection interrupted by vertical eye movements).

In regard to nausea induced by pseudo-Coriolis exposure, our results indicate that although nausea can occasionally develop to some degree by visual stimulation alone, it is more intensely initiated when accompanied by vestibular stimulation (head movement) as seen when pitch or roll head movements accompany yaw vection (8).

TABLE 1
GRAYBIEL'S INDEX AND TIME OF SELF-VECTION ONSET DURING PSEUDO CORIOLIS STIMULATION

Graybiel's Index	Normal (n=15)		Unilaterals (n=18)		Bilateral (n=6)	
	# subjects (% of total) n=15	Onset self-vection (S)	# subjects (% of total) n=18	Onset Self-vection (S)	# subjects (% of total) n=6	Onset Self- vection (S)
0	4 (27%)	36	8 (44%)	36	2 (33%)	17
1	4 (27%)	40	3 (17%)	38	1 (17%)	34
2	2 (13%)	48	4 (22%)	25	2 (33%)	20
3	4 (27%)	24	1 (6%)	36	1 (17%)	20
4^+	1 (6%)	28	2 (11%)	62		

n = number of subjects
S = time in seconds

TABLE 2
EFFECTS OF PSEUDO-CORIOLIS STIMULATION

Subjects	Onset of Self-Vection (in s ± SE)
Normal n=15	37.2 ± 6.98
Unilaterals n=18	47.6 ± 7.67
Bilaterals n=6	20.2 ± 4.24

s = secs.

LEGENDS

Fig. 1 - Cylindrical room used to produce pseudo-Coriolis effects in normal and labrynthine defective subjects.

Fig. 2 - Pattern of controlled head movements used to induce pseudo-Coriolis effects. Times in (s.)

Fig. 3 - Effects of pseudo-Coriolis stimulation on Graybriel's Index score.

Phase
1 Control period
2 light spots moving, head stationary
3 light spots moving, intermittent head movement
4 light spots moving, continuous head movement
5 light spots moving, head stationary
6 light still, head stationary

* - denotes when the subject requested termination of head movement
† - denotes onset of self vection and the time of its occurrence

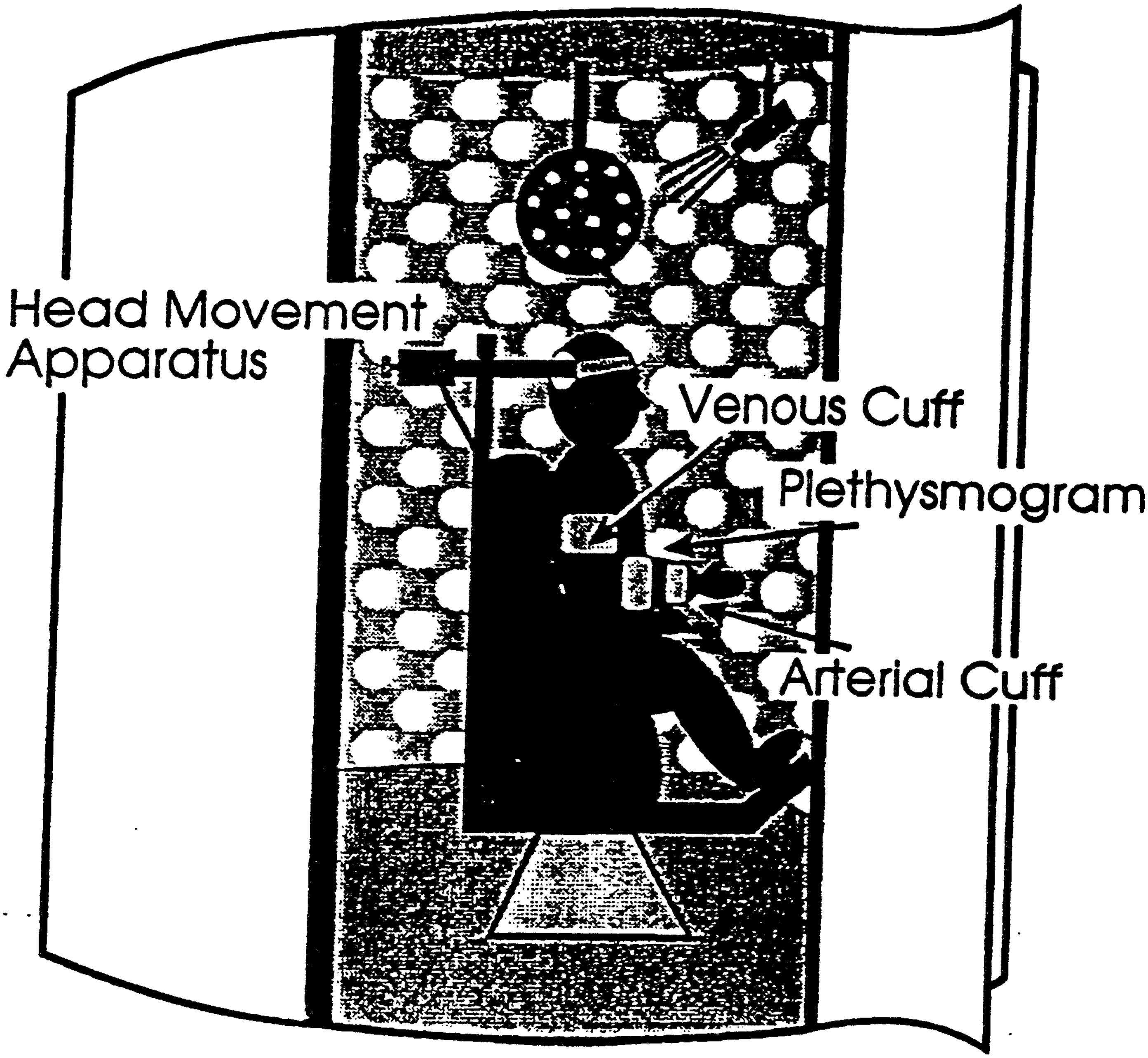
Head Movement Apparatus
Venous Cuff
Plethysmogram
Arterial Cuff

Figure 1

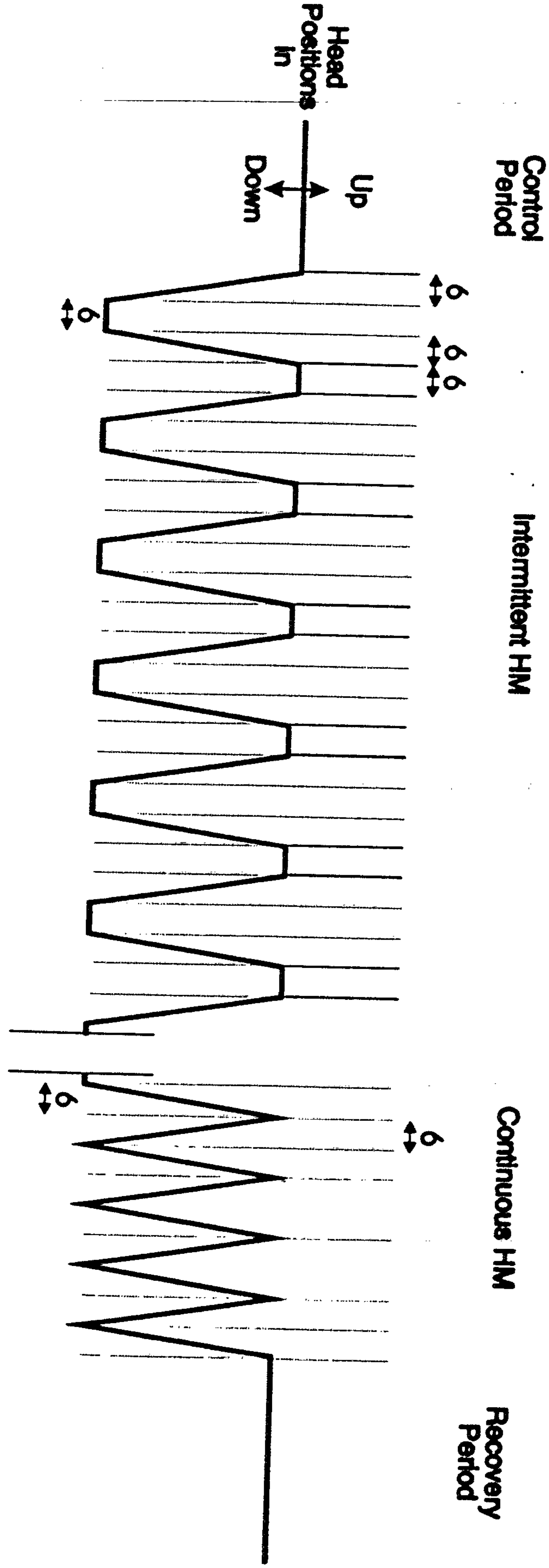
Head Positions in
Up
Down
Control Period
Intermittent HM
Continuous HM
Recovery Period

Figure 2

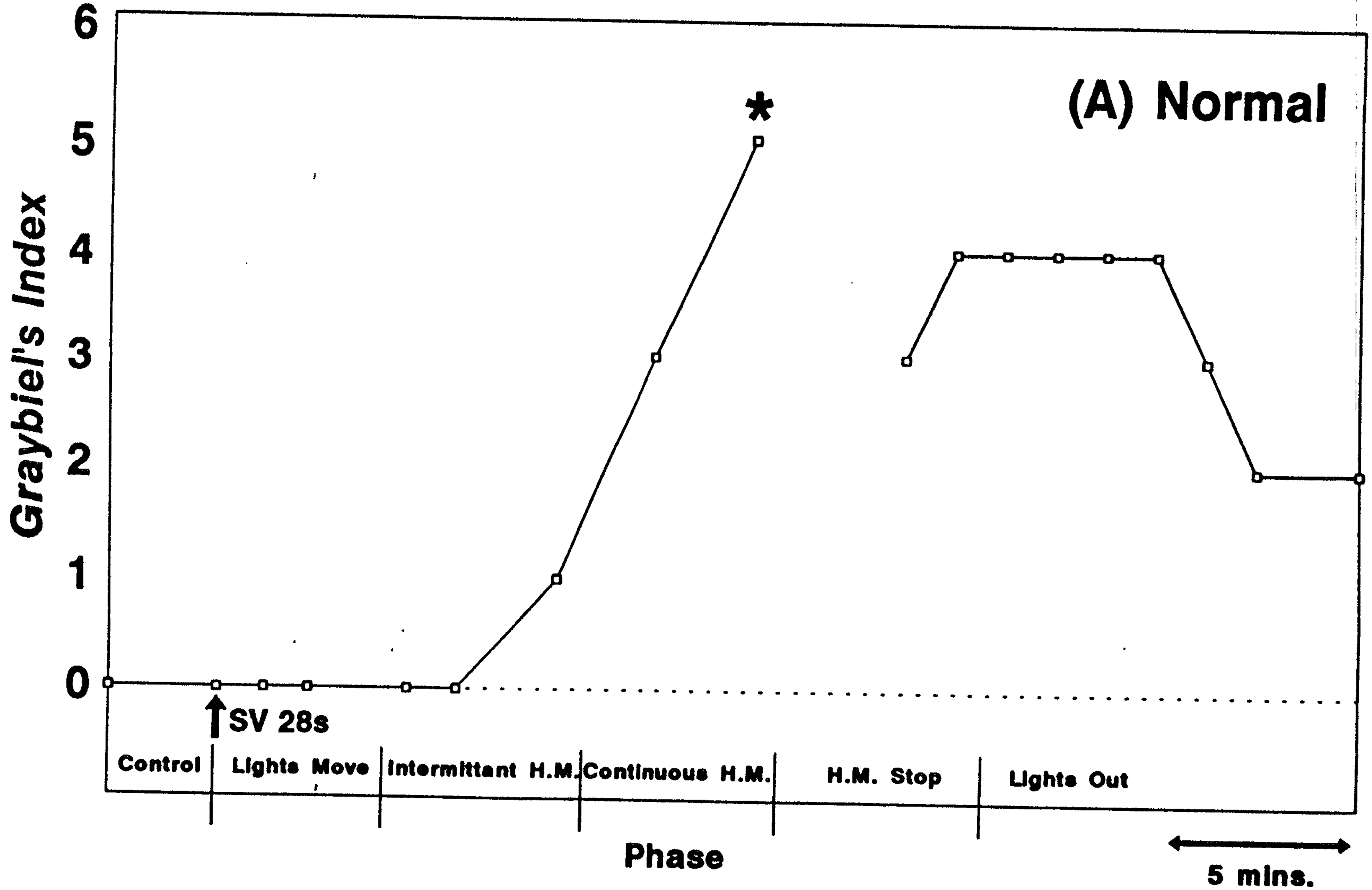
(A) Normal
Graybiel's Index
0
1
2
3
4
5
6
*
SV 28s
Control
Lights Move
Intermittant H.M.
Continuous H.M.
H.M. Stop
Lights Out
Phase
5 mins.

Figure 3 A

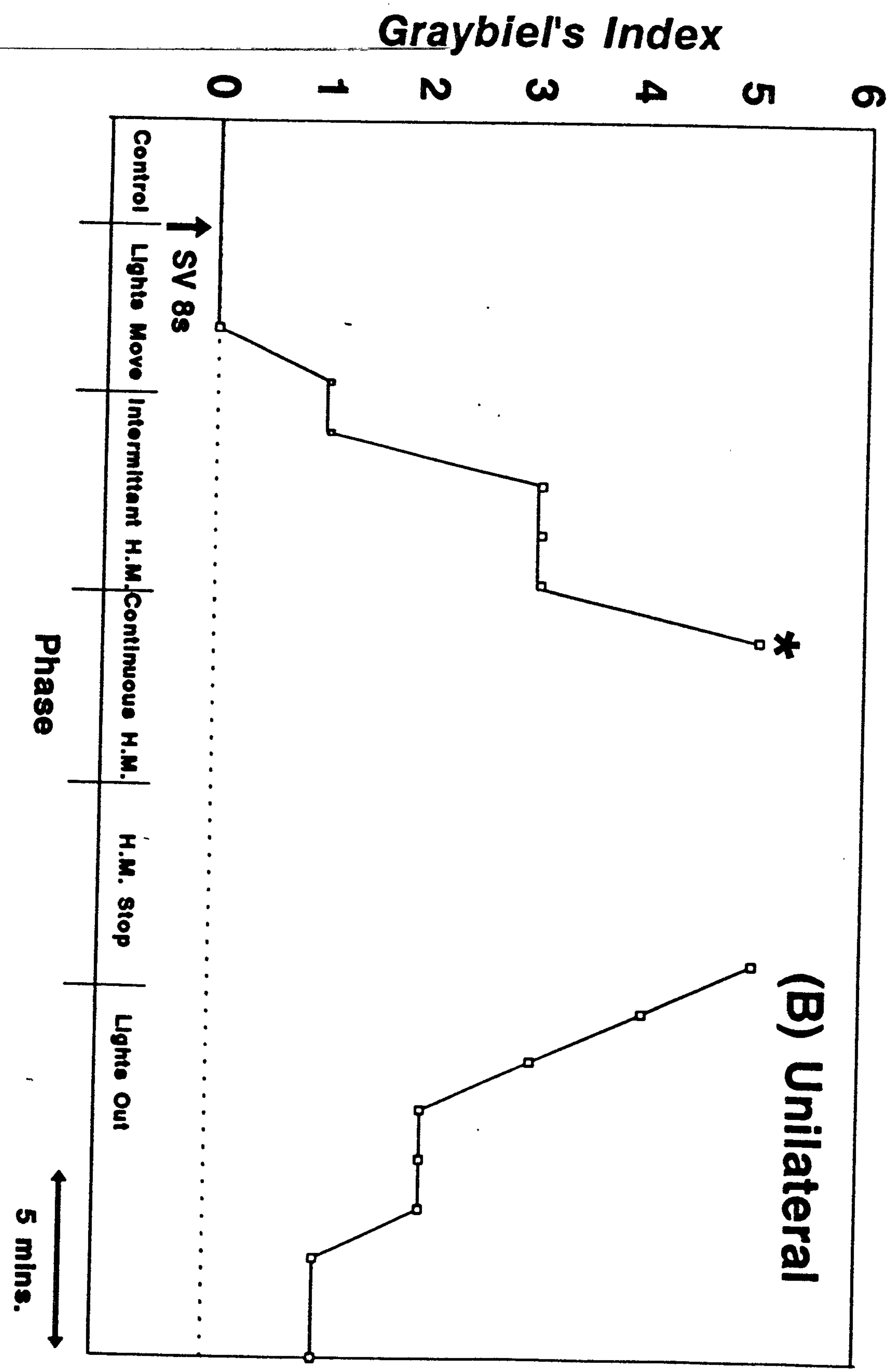
Graybiel's Index
0
1
2
3
4
5
6
(B) Unilateral
SV 8s
*
Control
Lights Move
Intermittent H.M.
Continuous H.M.
H.M. Stop
Lights Out
Phase
5 mins.

Figure 3B

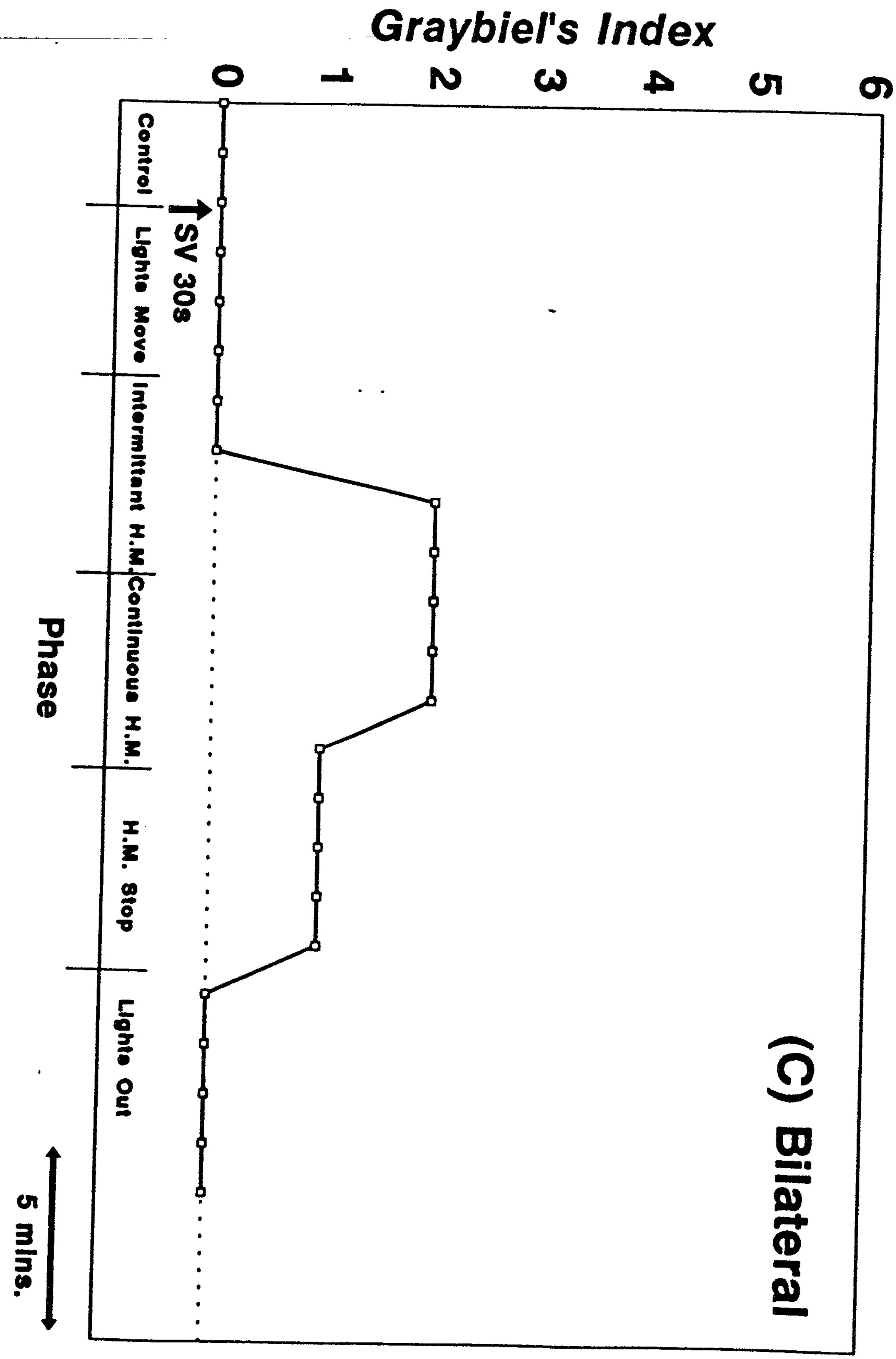
Graybiel's Index
0
1
2
3
4
5
6
(C) Bilateral
Control
SV 30s
Lights Move
Intermittent H.M.
Continuous H.M.
H.M. Stop
Lights Out
Phase
5 mins.

Figure 3C

.... Part II

Effects of Visual Field Characteristics on the Intensity of Self-Vection and Nausea

INTRODUCTION

Since the characteristics of the visual fields to which a low flying pilot will be exposed to in actual flight varies, it was decided to evaluate the relative effectiveness of color and visual area so that the results could be applicable in the construction of flight simulators.

METHODS

The same cylindrical room shown in Fig. 1 (Part I) was used. In these tests, however, two modifications were made namely: (1) by the intervention of appropriate monochromatic filters the moving spots of light were either white, yellow, red, green or blue. As to the area of the visual field effects, the total areas to which the subjects were exposed was reduced in stages from that shown in Fig. 1 (Part I) to a minimum of 40 x 60 cms. The relative provocativeness of the various visual fields, both in regard to color and area, were measured by determining the times in seconds required to induce the start of self-vection which then remains continuous.

RESULTS and CONCLUSIONS

A total of 17 normal healthy adult subjects were exposed twice to five different colours (white, blue, yellow and red) and four different areas of visual fields for a total of 170 tests.

SUBJECT TEST	WHITE	BLUE	YELLOW	GREEN	RED	LEAST PROV.
1	10 sec	12 sec	18 sec	6 sec	?	Yellow
2	7	3	4	4	3.5	White
3	9	8	8	7	7.5	?
4	10	8	10	11	16	Red
5	7	10	7	8	8	Blue
6	9	8	10	7.5	10	Yellow
7	6	5	5	5	5	?
8	4	5	4	6	7	Red
9	9	7	11	8.5	7.5	Yellow
10	6	5	6	7	5	?
11	12	10	12	11	11	?
12	6	5	4	2	2	?
13	8	8	13	7	7	Yellow
14	4	5	2	4	4	?
15	5	5	13	7	7	Yellow
16	13.5	7	8	9	16	Red
17	10	8	13	14	11	Yellow/Green

The relative effectiveness of various areas of the entire visual area in the rapidity of self-vection onset was determined and the results showed that as the area of the visual field diminished from a total exposure (see Fig.1 of Part I) the time of onset of self-vection became more rapid as the visual are decreased. This was accomplished by interfacing picture forms of various sizes through which the subject viewed the moving visual field. A maximum effect (most rapid time for onset of self-vection) when the subject field of vision was reduced to 40 x 60 cms. This finding indicates that flight simulator construction should ensure clear uniform canopy construction.

In regard to color, although there were some inconsistencies among subjects when comparing the relative provocativeness of different colors in the rapidity of the onset of self-vection, it would appear that blue was most provocative while yellow and white were least provocative. It seems apparent that inconsistency of the onset response could well be the result of inability to accurately recognize the starting point (time of onset) of the subjective sensation of self-vection when exposed to the moving visual field. It now appears, however, that the application of a newly published technique to this study would greatly improve the accuracy and reliability of the findings. Furthermore, the time of onset of self-vection would automatically be recorded graphically without the subject having to "guess" the time (and duration of onset). Essentially, this improved technique involves the recording of Cortical Evoked Responses using Encephalography Equipment with associated computer analysis of the responses. (See attached reprint). St. Michael's Hospital has a very competent and experienced technical staff in the Department of Neurology which would provide assistance in establishing the required procedure.

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