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MOTOR EFFECTS FROM VISUALLY INDUCED DISORIENTATION IN MAN

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I. Introduction

It has long been established by subjective observations that movements of the optical environment can produce visual disorientation. An example would be the sensation of one's own movement when looking down on flowing water from a bridge. In the absence of other clues which permit correct orientation in space, such visually evoked disorientation could affect pilots adversely. This would be especially the case when optical reference cues, such as the horizon, are obscured. Presently many aircraft accidents are attributed to disorientation arising from vestibular stimulation[4 6]. However, it is often evident that the contribution of visual disorientation to such accidents has not been sufficiently disinguished from labyrinthine disorientation[5 7]. The salient characteristics of optical disorientation in space therefore need to be defined. There are two aspects to a proper definition. The first facet is the subjective sensation of egocentric dislocalization, which one experiences as a "feeling" of being moved when looking at water passing under a bridge. By proper feedback mechanisms from nonvisual sensory input the person may compensate for his sensation of disorientation and thereupon act appropriately with respect to his objective environment. The second facet is the behavioral effect of optically induced disorientation which a person is not necessarily aware of subjectively. One of the effects of disorientation might manifest itself in changes of various types of motor actions leading to an abnormal motor behavior.

For the above reasons we attempted to elucidate the problems of orientation of persons placed in a moving optical environment. Little seems to be known about visually induced motor reactions of man in this situation in which input from all other sensory modalities remain normal[5]. Considerable work on this topic has been done with animals[1 3]. In the present study walking was chosen as a simple motor activity to find out whether it is affected by a movement of the entire optical surrounding when all stationary visual clues are eliminated. Disorientation would then manifest itself if a person, intending to walk in a straight line, should deviate from it.

One would expect walking in a straight path to be unchanged from the normal if stationary auditory, vestibular, and proprioceptive stimuli are prepotent over the visual input. On the other hand, one would expect to find deviations from a straight walking path if visual stimuli should override the input from the other sensory modalities. The purpose of this paper was to investigate whether or not measurable changes in motor activity can be visually induced and, if this should be the case, to explore factors influencing this phenomenon.

II. Methods

The tests were conducted in a cylindrical motor driven optokinetic drum rotating unidirectionally around the vertical axis either clockwise or counterclockwise (Fig. 1). Part of the top and bottom were conical in shape to occlude any outside stationary objects from the subject standing inside the drum. The bottom of the drum had an opening of sufficient diameter to permit a person to walk 28 inches in one direction on the stationary floor beneath the drum. The drum was suspended so that the bottom of the cone-shaped rim was 26 inches from the floor. The drum was 65 inches high and 48 inches in diameter at its widest part. Alternating black and white vertical stripes 1.5-inch wide constituted the total visual environment for the subject. In order to eliminate visual clues from a stationary light source, the inside of the drum was illuminated from the top with a battery operated fluorescent light which rotated as part of the optical environment.

A pen was taped to the outside of the subject's left foot. As the subject walked backwards and forwards in the drum, the pen traced a record of his walking on paper fixed to the floor underneath the drum.

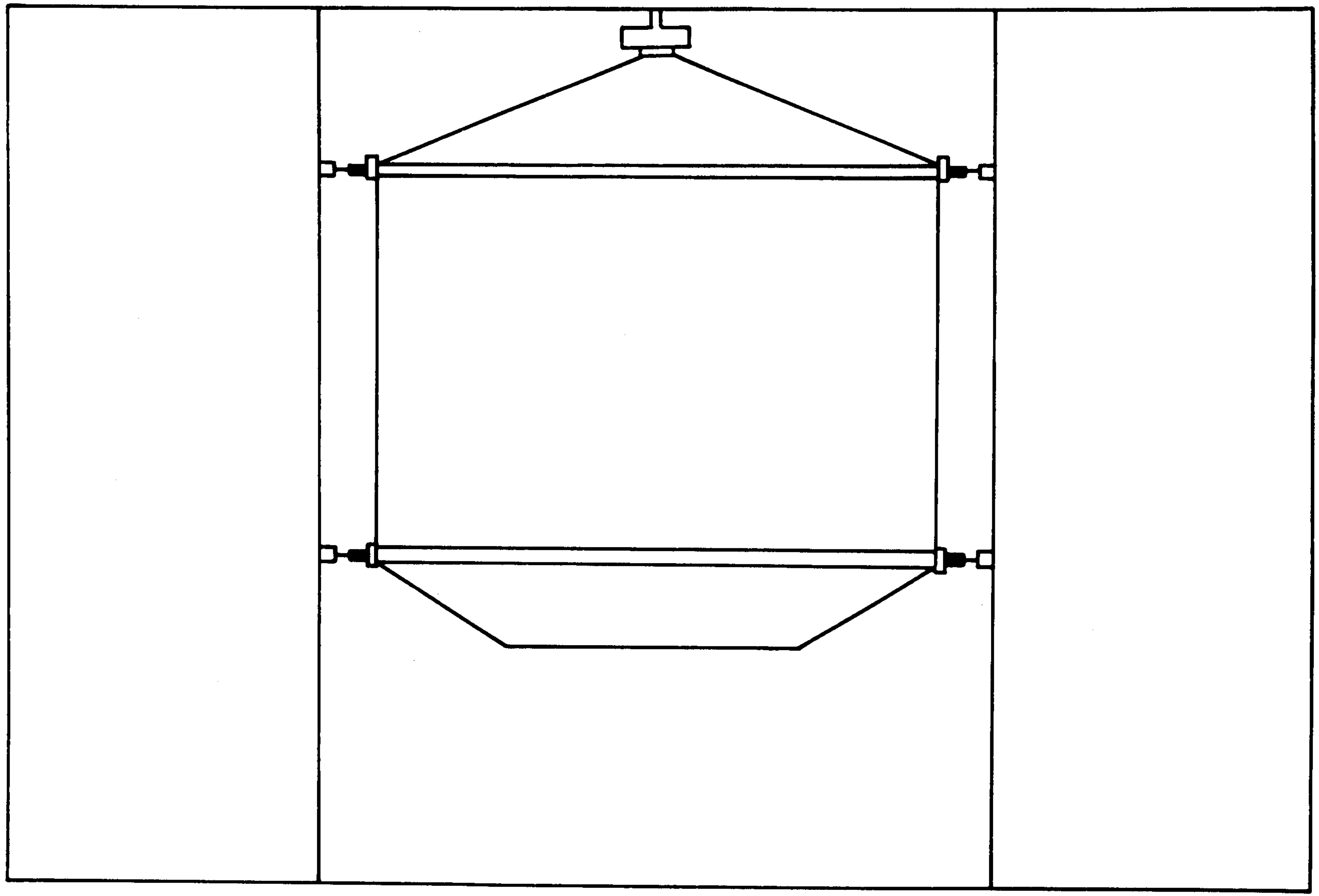

FIGURE 1. Vertical cross section of optokinetic drum suspended from the top of a frame which is indicated by vertical and horizontal lines. The trapezoid (conical) upper and lower parts rotate as extensions of the cylindrical part and exclude any stationary object from view of the subject inside the drum.

Before entering the drum all subjects were determined to have normal vision and given the same instructions. First, they were told to slide their feet slowly, using small steps so that the pen remained in continuous contact with the recording paper. A walk from one side of the cylinder to the other took 6±2 seconds when the subject moved in this manner. Secondly, the subjects were instructed only to look up to exclude peripheral vision of the floor and to try to watch a particular horizontal line which went completely around the upper area of the inside of the drum. Thirdly, the subjects were asked to walk in an absolutely straight line and they were told to try to remain exactly in the same straight path as they walked back and forth.

On each test the subject was asked to walk first forward and then backward till he had completed a total of nine walks. Five seconds were allowed between walks. After the ninth walk the subject was asked to step out of the drum. While the subject stayed outside, the recording paper was replaced and the drum speed altered as required by the test.

Before the beginning of each series of tests with the moving cylinder, the subject was requested to walk back and forth in a straight line in the stationary drum. The pattern of this walk was used as a control.

The degree of disorientation of the subject was obtained by measuring the angle formed by two successive walks, one forwards the other backwards (Fig. 2). If the subject is not disoriented this angle will be negligible or even unmeasurable. If the subject is disoriented, the second walk will not be in the same path as the first and the farther the subject has deviated from the first walk the more his disorientation and subsequent angle of deviation will be. For the control walk all deviations of successive paths were measured and the angles of deviation were given in absolute values. For the deviations occurring while the optical environment of the drum was moving, only those angles of deviation which pointed in the same direction as the movement of the drum were assigned positive values and the angles in the opposite direction of the drum's turning were represented as negative values.

The subjects were exposed to speeds ranging from 3 to 45 radians per minute and their angles of deviation were measured. During the tests the experimenter gave instructions from the same

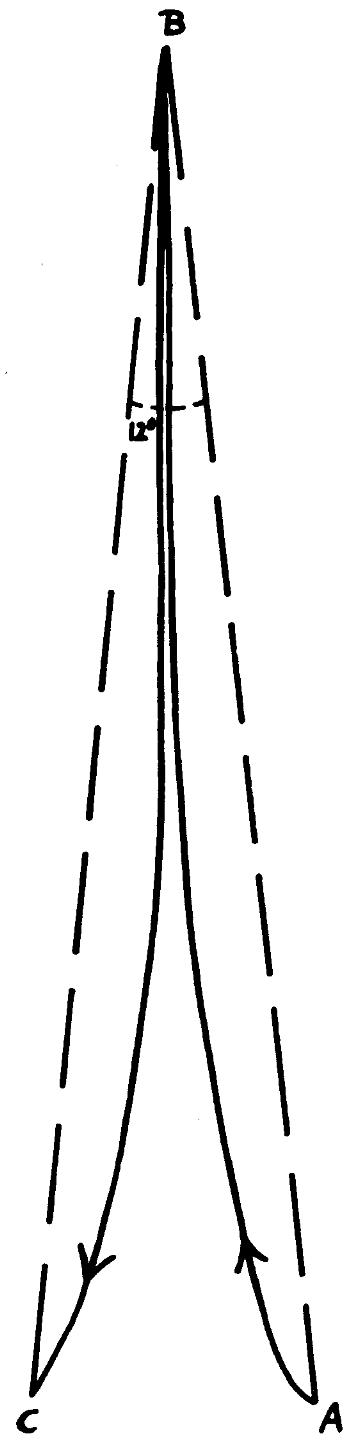

FIGURE 2. Typical walk pattern in a moving optical environment, clockwise at 3.1 to 9.0 radians/min. The solid line from A to B represents the first forward walk. The solid line from B to C represents the first backward walk. The angle between the broken lines is the first angle of deviation from a straight walk.

place in the room at all times to determine if the drum's optical influence could override this auditory orienting influence.

III. Results

The results were grouped in four parts to answer four separate questions which arose from the overall problem. Parts 2, 3, and 4 depended upon the outcome of the results obtained in Part 1. Since somewhat different experimental procedures were required in the four parts, their rationale is briefly introduced at the beginning of each part.

Part 1. Does the walking path in a stationary optical environment differ from that in a moving one? This part of the study was exploratory to find out whether motor activity as such was affected measurably by this type of visual stimulation.

After establishing the pattern of back and forth walking with continuously open eyes for each subject under the control condition of the stationary drum (Fig. 3), the cylinder was rotated at a constant speed and the walking paths recorded while the subject kept his eyes open all the time. Fifty-six tests were made at various drum speeds. The subjects were divided into seven groups so that deviations at different speeds of the drum could be measured and compared. The speeds into which the tests were grouped fell into the ranges shown in Table 1.

TABLE 1.—Deviation of path of subject, with eyes open and drum rotating at varying speeds

Group	No. of subjects	Range of radians/min.	Mean (± SD) of subjects' angle of deviation in degrees
1	8	90.0 to 0.0	2.5
2	8	3.1 to 9.0	12.0±6
3	8	9.1 to 15.0	19.0±11
4	8	15.1 to 21.0	23.0±12
5	8	21.1 to 27.0	23.0±17
6	8	27.1 to 33.0	31.0±16
7	8	33.1 to 39.0	34.0±23
8	8	39.1 to 45.0	37.0±17

T between groups 1 and 2 = 8.1666, p M. 05 F between groups in the moving environment = 2.5, p M.05

FIGURE 3. Tracing of a representative experiment during a control walk in the stationary optokinetic drum.

The results are presented in Table 1. It was evident that motor disorientation occurred consistently when the total visual environment was moving. This effect was even noticeable in those subjects who, being exposed to the slowest rotation (3 to 9 radians/min.), deviated least. These subjects deviated significantly more than they did in their control walks (T=8.2, N=8, $p<0.01$). Furthermore, the results indicated that there was a positive association between the degree of disorientation, as measured by the angle of deviation from the control, and the speed of the drum. When the tests were divided into seven groups on the basis of the speeds of the drum the analysis of variance test revealed a significant ($F=2.4995$, $p<0.05$) positive interaction between the degree of disorientation and the speed of the total optical environment.

The walking patterns of the subjects in three representative experiments corresponding to three different speeds are depicted in Figs. 2, 4, and 5. The angles of deviation which have been measured in these tracings were entered on each of the figures.

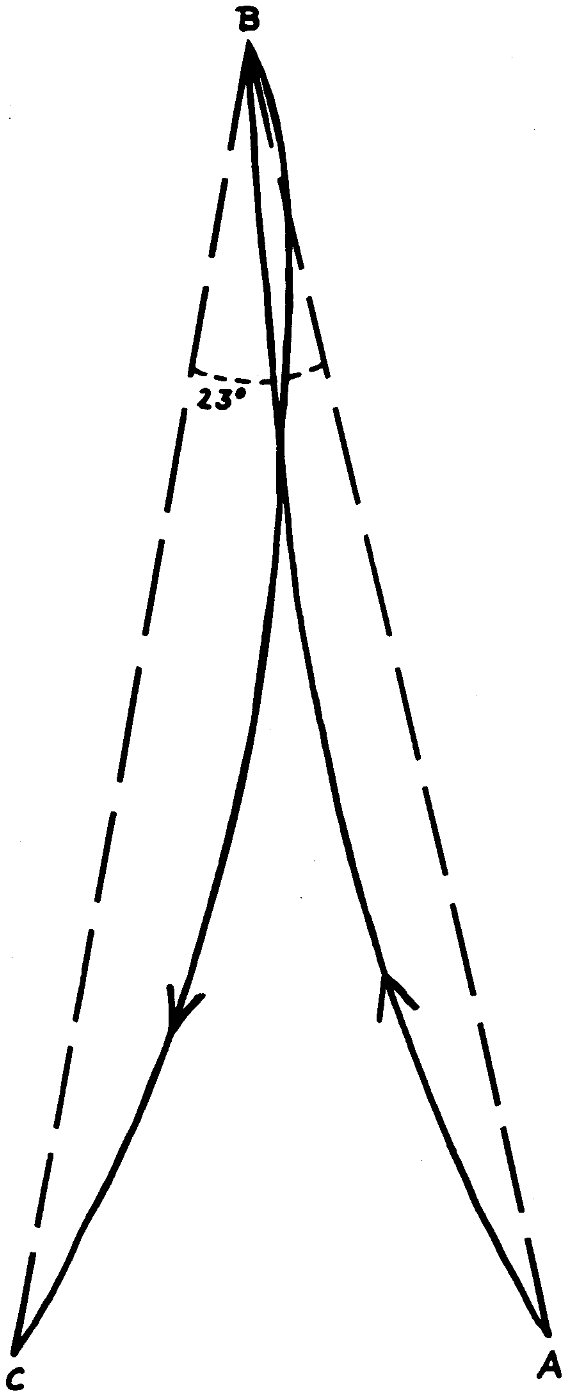

FIGURE 4. Walk pattern in an optical environment moving from 21.1 to 27.0 radians/min. (see Fig. 2).

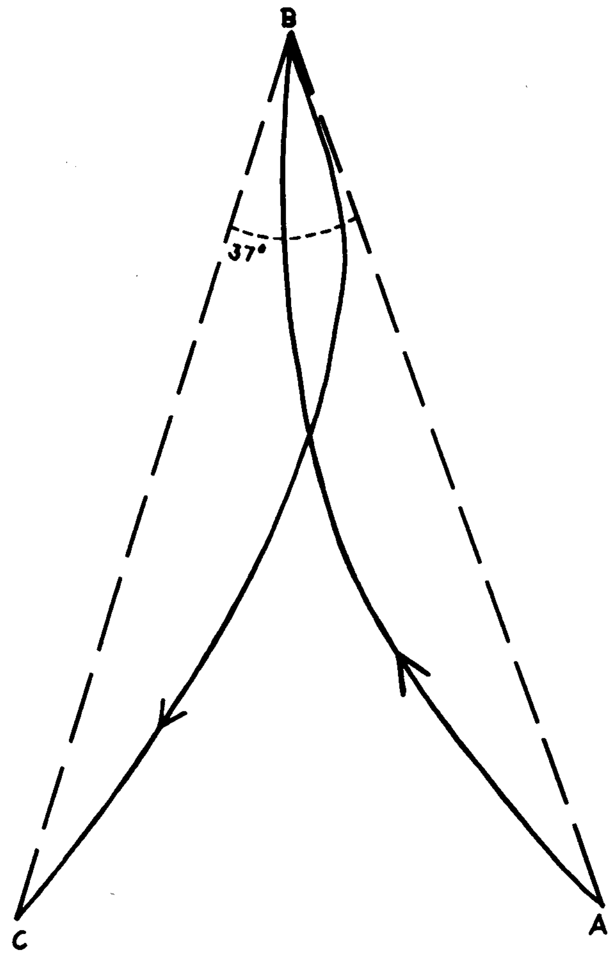

FIGURE 5. Walk pattern in optical environment moving from 39.1 to 45 radians/min. (see Fig. 2).

Part 2. The problem posed here depended upon the results of the tests reported in Part 1. In Part 1 it was found that a person who was stimulated by a moving environment while he was walking would become disoriented in his walking behavior. In Part 2 the question is asked whether it is necessary for the subject to be stimulated only during motor activity to bring about disorientation. This was done by exposing the subject to the rotating drum while he stood still and having him close his eyes immediately before and during walking. If the subject is influenced in his walking behavior only by his exposure to the drum prior to walking, his disorientation may be attributed to the moving environment.

If the subject walking with closed eyes does not become disoriented after prior exposure to the moving drum while standing quietly one must conclude that the motor activity itself may be necessary for disorientation to occur.

In principle, the same procedures were followed as in the first part. Six subjects were placed in the drum at a speed of 9±1 radians/min. First, control tracings of walking patterns were made with the subject keeping his eyes continuously open such as in Part 1. Then tracings were recorded in the experimental situation in which the subject had his eyes open for a period of 5 seconds while standing and closing them before starting to walk, keeping them closed during the walking.

All subjects who walked with closed eyes after exposure to the moving environment displayed disorientation (Group II, Table 2). Their deviation from the control paths in the stationary cylinder was significant. In fact, it was almost as marked (insignificantly different) as the angles of deviation observed in subjects who walked with continuously open eyes. The subjective phenomenon of disorientation did not differ substantially from that observed among persons tested with continuously open eyes (Part 1).

TABLE 2.—Deviation of path of subjects with eyes closed compared with control and eyes open condition

Subject No.	Group I Eyes open speed 0 radians/min. (degrees)	Group II Eyes closed speed 9±1 radians/min. (degrees)	Group III Eyes open speed 9±1 radians/min. (degrees)
1	2	17	22
2	1	3	14
3	3	9	10
4	2	4	13
5	3	12	16
6	2	9	13
Total	13	54	88
Mean	2	9	15

T between groups I and II = 3.43340, p M.05
T between groups II and III = 2.51111, p M.05

Part 3. Based on the experience reported in Part 1 that everyone became disoriented when walking back and forth with open eyes in the drum the question arose whether intermittent periods of nonstimulation would alleviate or counteract the disorientation.

Six subjects were tested in the drum by walking back and forth as in Part 1. However, each time when they had reached the farthest point of back or forward walking they closed their eyes and stood quietly for 5 seconds. The control tracings obtained in the stationary drum were then compared to those found with the experimental situation of intermittent stimulation.

All subjects who had nonstimulatory "rest periods" with closed eyes between their walks deviated significantly from the control pattern in the stationary environment (Table 3). In these persons the angles of deviation were almost as marked as in those who kept their eyes open continuously. There was no noticeable difference in subjective disorientation between persons who closed their eyes intermittently and those who left them open all the time.

TABLE 3. Deviations of subjects with eyes open only while wslking compared to the control and the eyes open only while standing

Subject No.	Group I Speed 0 radians/ min. (degrees)	Group II Intermittent stimulation eyes open while walking only. Speed 9±1 radians/min. (degrees)	Group III Eyes open all the time Speed 9±1 radians/min. (degrees)
1	2	7	22
2	1	6	14
3	3	9	10
4	2	24	13
5	3	22	16
6	2	11	13
Total	13	79	87
Mean	2	13	15

Part 4. Since the methods and results described in Parts 1, 2, and 3 permitted an objective measure of the degree of optical disorientation in space, it was of interest to find out whether subjects could be trained to overcome the disorienting effects.

Two procedures were tried. In one procedure the subjects were told to counteract the influence of the drum on their walking behavior by walking in a direction opposite to that in which the drum induced them to walk. In another procedure, subjects were asked to counteract the influence of the drum on their walking by timing the drum's movement so that the drum's apparent speed was noted. If the person walked in the same direction as the drum's movement the apparent speed of the drum became slower. It was reasoned that if the apparent speed of the drum remained constant or increased for the person, he should not exhibit disorientation in his walking.

Although a few subjects were able to counteract the influence of the drum by using either or both of the training procedures, most subjects reacted unpredictably by overcompensating or undercompensating.

IV. Discussion

The fact that subjects are influenced by the drum regardless of whether they are walking or not indicates that the disorientation induced in these experiments does not depend on the subject's walking during the visual stimulation. Disorientation has merely been measured by recording the subjects' motor activity through walking patterns, and this disorientation will occur whether the subject is moving or stationary.

The effects of different speeds of visual stimulation require further investigation and quantification. The present results indicate the subject's disorientation does not increase linearly with increments in drum speed.

The apparent different effects among subjects who have been given the training procedures require further investigation. At present, it is not known if these differences may be due to personality, motivation, or some basic orienting ability.

The results of this study are applicable to situations involving the loss or malfunction of flight instruments under IFR conditions. Under those conditions, and particularly at night, the pilot may experience disorientation arising from the sweep of the beam from the rotating beacon. The acceleration resulting from inappropriate roll axis compensation could cause further disorientation arising from labyrinthine stimulation, thus compounding the problem and leading to disastrous consequences. The danger has not been fully recognized in the past. If rotating beams of light are to be used, beacons should be arranged to counter-rotate and thus cancel the disorienting effects.

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