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PERCEPTION OF THE VISUAL HORIZONTAL IN NORMAL AND LABYRINTHINE DEFECTIVE SUBJECTS DURING PROLONGED ROTATION

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UNITED STATES NAVAL SCHOOL OF AVIATION MEDICINE

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PERCEPTION OF THE VISUAL HORIZONTAL IN NORMAL AND LABYRINTHINE DEFECTIVE SUBJECTS DURING PROLONGED ROTATION*

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SUMMARY PAGE

THE PROBLEM

This experiment was designed to compare the effects of prolonged centripetal acceleration on the perception of the visual horizontal in normal and labyrinthine defective men.

FINDINGS

Following an increase in centripetal acceleration the normal men showed a rapid change in the perception of the visual horizontal (the oculogravic illusion) for one to two minutes and no systematic change thereafter for one hour. In contrast, the labyrinthine defective men showed a smaller, rapid, and then gradual change in the perception of the visual horizontal throughout one hour of constant rotation. At the end of one hour there was no statistically significant difference between the two groups.

INTRODUCTION

It is well known that both normal and labyrinthine defective (L-D) subjects can set a luminous line to the horizontal in darkness with small error when they are seated erect and stationary (5). It is also well known that when normal subjects are quickly accelerated to a constant angular velocity at some distance from the center of rotation of a rotating room, two effects occur: 1) There is a slow change in the perceived visual horizontal so that it tends to become close to the horizontal which is established by the resultant of gravity and centripetal force. This gradual change in visual orientation has been termed the lag effect of the oculogravic illusion, and its duration is between one and two minutes (7); 2) after the lag effect terminates, there is little or no systematic change in the perceived visual horizontal, at least up to four hours (1). The lag effect has also been reported for L-D subjects, but it was less clearly defined (7). No data are available on the perception of the visual horizontal over a prolonged period of constant rotation in L-D subjects. Furthermore, the observations of the perception of the visual horizontal by normal subjects made during the four-hour exposure to constant centripetal acceleration were made only every ten minutes.

It was the purpose of the present study to make frequent observations of the perceived visual horizontal (oculogravic illusion) in normal and L-D men over a period of one hour of constant rotation, including both the two-minute period of the lag effect and subsequent period of constant rotation to determine any systematic changes in the lag effect under these conditions.

PROCEDURE

SUBJECTS

Five normal men including one of the authors were studied. All had normal nystagmus responses to caloric stimulation, normal responses to rotation, and had experienced the oculogravic illusion in other experiments. Nine labyrinthine defective men were also studied. All of them were deaf and had acquired their deafness in childhood as a sequela of meningitis. All of them had abnormal vestibular responses to caloric stimulation and rotation.

APPARATUS

All of the observations were made in the Pensacola Slow Rotation Room which has been described in detail elsewhere (8). The velocity used in this experiment was 14.0 RPM in a counterclockwise direction, which could be produced in from three to four seconds and maintained within an error of 4 per cent. The subject was seated in a special chair located within a light-proof compartment at the periphery of the room so that his head was 5.5 feet from the center of rotation which produced a change in the direction of resultant force (phi) of 20° at the subject's head. A Fiberglas head holder bolted to the chair, a seat belt, and other supports maintained him in a fixed though comfortable position, facing the direction of rotation. The subject observed a luminous line broken in the center with a spot. The luminous line was within a collimator mounted rigidly directly in front of the subject. Either he or the experimenter could control the position of the luminous line by turning a knob, and its position was recorded on a large dial in a second compartment. The experimenter reported the readings to a recorder in the control room through a special communication system so the subject could not hear them. Thus, the subject could indicate his perception of the visual horizontal as a function of time following a rapid change in resultant force and subsequent constant rotation.

METHOD

Each series of observations began with the room stationary. The luminous line was offset from horizontal in a clockwise direction, and then it was set to horizontal. Five such offset readings were made while the room was stationary. The room was then accelerated quickly to produce a change in phi of 20°. The line was offset and the subject immediately set it to horizontal and maintained it in this position. At fifteen seconds following the beginning of rotation and at every subsequent fifteen seconds up to two minutes, the experimenter made a reading and offset the line as before. The luminous line was turned off after the two-minute reading and remained off for forty-five seconds. During this period it was offset to a prearranged position, and when the luminous line was turned on, the subject set it to horizontal. The experimenter made a reading at three minutes and turned it off again for forty-five seconds. Subsequently, readings were made every minute for sixty minutes. The offsets were prearranged to make the subject's task fairly difficult. The reference point was always his last setting. For the two-minute setting it was offset from the previous setting clockwise (+) 10°; at three minutes it was offset counterclockwise (-) 10°. Suceeding offsets were +20°, -20°, +30°, and -30°. This sequence was then repeated until the 58 additional settings were made. The oculogravic illusion was measured by determining the deviation of the subject's settings from his static settings. This procedure obtained a record of the subject's perception of the horizontal as a function of time following a change in the magnitude and direction of resultant force acting on him, or in other words gave a measure of the oculogravic illusion (5).

RESULTS

The results showing the change in setting to the horizontal as a function of time for the five normal and the nine L-D subjects are presented in Figure 1. The same data combined into blocks of five one-minute settings are to be found in Table I. The lag effect was clearly present for both groups (Figure 1). There was a sharp increase in the oculogravic illusion for about sixty seconds and then a slight reduction with a leveling off thereafter. On the other hand, the normal and L-D subjects differed from each other in two significant ways: First, at the termination of the lag effect, the normal group made settings to the horizontal which were closely in accord with the change in the direction of the resultant force; i.e., the oculogravic illusion was approximately 20° (Figure 1, Table I) while the illusion was only about 12° for the L-D group. Second,

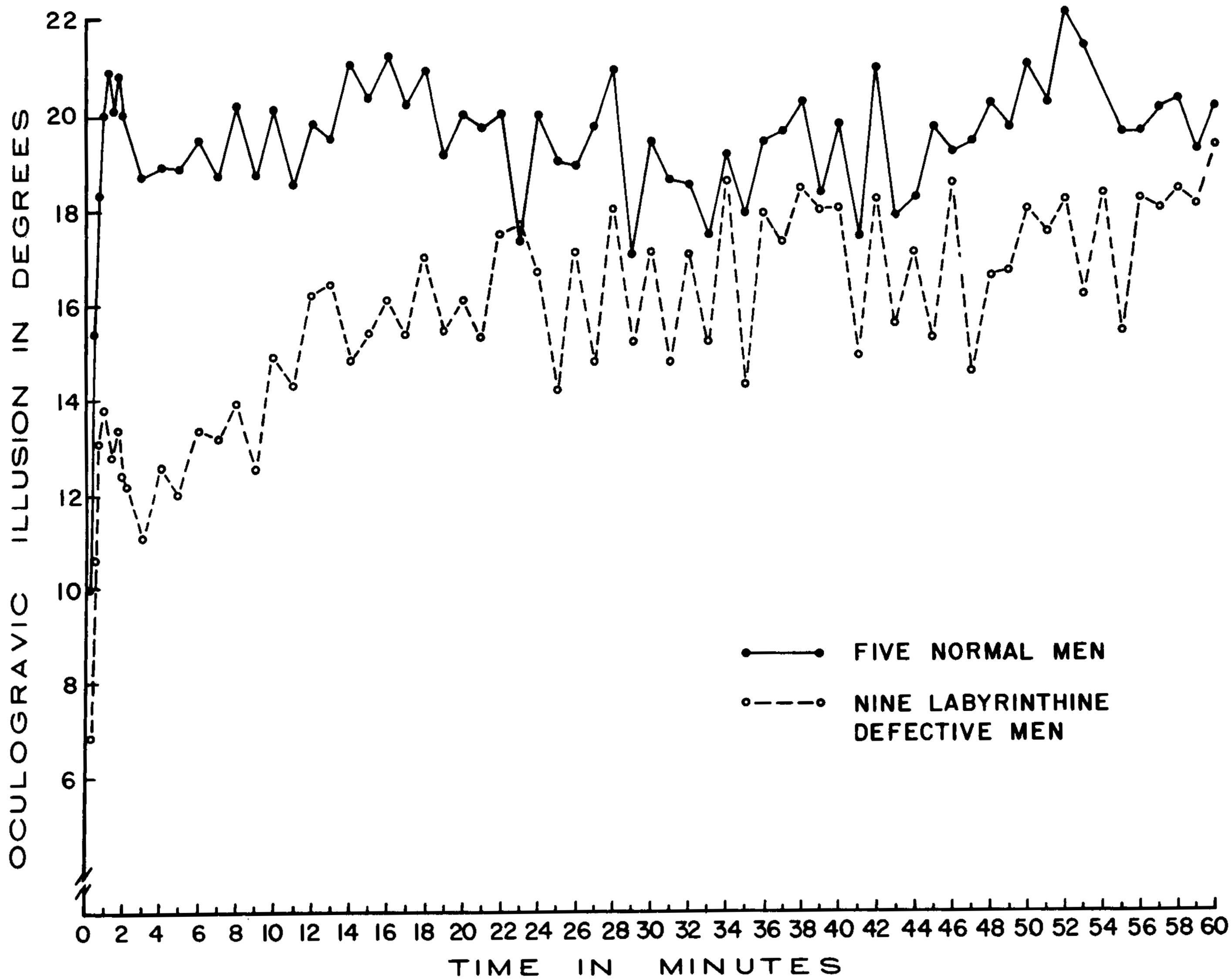

Figure 1

Change in the Oculogravic Illusion in Degrees During One Hour of Constant Rotation

Table 1

Mean Oculogravic Illusion in Degrees for Blocks of Five Trials Following Abrupt Acceleration to Constant Velocity in a Rotating Room

Blocks of Trials	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
Normal Subjects	19.3	19.5	19.8	20.3	19.2	19.6	18.3	19.4	18.8	19.9	20.8	19.8
L-D Subjects	12.3	13.6	15.4	16.1	16.3	16.4	16.0	17.9	16.2	16.9	17.1	18.4
Diff.	7.0	5.9	4.4	4.2	2.9	3.2	2.3	1.5	2.6	3.0	3.7	1.4

the settings of the normals did not show a systematic change following the lag effect whereas the L-D subjects showed a continuous increase in the illusion throughout the one-hour period of the observations. These differences are clear from an examination of the data (Figure 1, Table I).

A trend analysis (10) was performed for the two groups independently, combining the data in blocks of five one-minute trials. The test for trend for the normals was not significant ($p > 0.10$), while the L-D subjects exhibited a significant trend in the direction of an increase in the oculogravic illusion throughout the hour of testing ($p < 0.01$). Over the first block of five settings (Table I) the median test (13) showed that the normal group had a significantly greater illusion ($p = 0.03$), but over the settings from 56 to 60 minutes the difference between the two groups was not significant ($p = 0.37$). Thus, although the normals showed a consistently larger mean oculogravic illusion throughout the hour of settings to the horizontal during constant rotation, at the end of the period the difference was only 1.4° and not statistically significant. It should be noted that nonparametric analyses have been used here because the variance in performance was substantially greater for the L-D than for the normal group. This very large variance of the L-D group was a crucial factor in the failure to find a statistically significant difference between the two groups during the final trials (cf ref. 7).

DISCUSSION

The results of this experiment support the results of earlier experiments (2,6) for normal subjects in that a lag effect was present and also in that, for frequent measurements following this initial period, there was no systematic change in the effect. The data showing a greater oculogravic illusion in normal than in L-D subjects for short periods of observation have also been reported (7). On the other hand, the finding that, after prolonged exposure to a change in magnitude and direction of resultant force, the L-D subjects closely approximated the settings of the normals has not been found elsewhere in the literature. Consequently, this prolonged lag effect requires special comment with regard to the possible sensory processes involved.

It has been widely assumed that the otolith organs play a crucial role in the perception of the postural vertical in normals, but the experimental evidence shows that although L-D subjects make greater errors, the differences between their average settings and those of normals are small, particularly after practice (2). This makes it clear that other gravitational receptors are involved in this task. It has also been shown that L-D subjects are more affected by prolonged bodily tilt than are normals (3). There is extensive evidence that the otolith organs play a key role in the perception of the oculogravic illusion (7). The L-D subjects differ significantly from normals in both the static and the dynamic phases of the illusion for observations made over a period of two or three minutes. The fact that the magnitude of the oculogravic illusion increases throughout the one hour of constant rotation for the L-D subjects suggests that information from other sensory mechanisms becomes crucial in the perception of the visual horizontal.

In normals the lag effect appears to be due to a gradual change in the relative weighting of visual and vestibular information over time (9). It is suggested that in normals the information from the otoliths is more heavily weighted than data from tactile and proprioceptive receptors. On the other hand, in subjects with defective labyrinthine function, the information from the tactile and proprioceptive receptors must predominate. It is further suggested that for L-D subjects the rapid change followed by a gradual change in the oculogravic illusion may be associated with differential weighting of information from the highly complex sensory mechanisms involved in tactile and proprioceptive perception (12). It has been shown that for both of these sensory processes there are individual fibers which adapt slowly and others which adapt rapidly. For example, Löwenstein (11) has found that fibers from certain stretch mechanoreceptors in the skin of the frog "---show no signs of adapting to zero over the period of 40 minutes of observation," whereas Gray and Matthews (4) reported that fibers from the Pacinian corpuscles in the cat's toe adapt in about two minutes. Thus, it would appear that immediately following a change in the direction and magnitude of resultant force acting on an L-D subject, there would be a relatively large amount of synergistic information from several tactile and proprioceptive receptors in support of a new spatial orientation and opposed to the visual information. This would be expected to produce an initial, rather rapid change in orientation, but as the adaptation process progressed (e.g., in Pacinian corpuscles), information from the slowly adapting receptors would become more heavily weighted and, over time, would lead to an orientation to the resultant force similar to that of normals. It should be kept in mind that for subjects with normal vestibular information available, the otolith information receives the heavier weighting, and the lag effect is relatively short. Thus, it would appear that adaptation processes associated with differential weighting of sensory information (9) over time will lead to the lag effect in both normal and L-D subjects but with different sensory processes involved in the two groups.

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Five normal and nine labyrinthine defective men were studied in a Slow Rotation Room which produced a change in resultant force of 20° on them. The men faced in the direction of rotation and at one minute intervals set a luminous line to the perceived horizontal in darkness for one hour. The results for the normal men confirmed an earlier study showing no systematic change in the perception of the visual horizontal after an initial lag effect. In contrast, the labyrinthine defective men showed a smaller, rapid, and then a gradual change in the perception of the visual horizontal throughout the one hour of constant rotation. At the end of one hour there was no significant difference between the two groups. These results are discussed in terms of a differential weighting of the synergistic information available to the two groups.

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