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INFLUENCE OF CONTACT CUES ON THE PERCEPTION OF THE OCULOGRAVIC ILLUSION*

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SUMMARY PAGE

THE PROBLEM

The purpose of this experiment was to study the influence of otolith and nonotolith information in the perception of the visual horizontal during rotation. Five normal men and five men with defective labyrinthine function acted as observers. All measurements were made in a room which could be rotated. Initial, static measurements were made while the men stood erect in the stationary room. Similar measurements were made during rotation while the observer stood on a platform set to the resultant horizontal with head and body aligned with resultant force. Data were also obtained with three other combinations of head and body position. This procedure was designed to produce two situations for the normal men in which otolith and nonotolith information were synergistic and three others in which they were antagonistic.

FINDINGS

The results showed that the perception of the visual horizontal during rotation in this situation is quite different from that found when the observer is rigidly supported in a chair during rotation. Settings to the visual horizontal during rotation were not systematically related to differences in head and body position nor were there significant differences between the normal and L-D men. The results show that nonotolith information predominates in this experimental situation. Furthermore, the data suggest that the spatial orientation of a pilot strapped in a cockpit may be somewhat different from his spatial orientation when he is standing on a rotating space platform.

INTRODUCTION

The purpose of this study was to investigate the role of otolith and nonotolith gravireceptors in the perception of the visual horizontal in darkness when observers stood on a rotating platform. It was hoped that the results would shed some light on the contribution of the nonotolith gravireceptors in the perception of the visual horizontal in normal and labyrinthine defective (L-D) men. It is well known that normal and L-D men show significant differences in such phenomena as counterrolling (1), the oculogravic illusion (2,3), and their perception of motion on a parallel swing (4). At the same time it is also well known that L-D men can compensate for the loss of vestibular function in certain situations. For example, Clark and Graybiel (5) have shown that in a series of 30 successive settings to the postural vertical both normal and L-D men made systematic improvement. The normal men showed smaller average errors, but the differences were small, particularly after 15 trials, and were not statistically significant. Specifically, the present study compares the performance of normal and L-D men with various head and body positions to determine their influence on the perception of the visual horizontal.

PROCEDURE

OBSERVERS

Five normal and five deaf L-D observers were studied. The normal men were medical students who showed normal responses to caloric stimulation (6) and to an ataxia test (7). The L-D observers had acquired their bilateral deafness in childhood as a sequelae of meningitis and showed abnormal responses to the caloric and ataxia tests. All of the men had had experience in making observations in rotating devices and with the goggle device used to measure the perception of the visual horizontal.

APPARATUS

The experiment was conducted on the Coriolis Acceleration Platform, a slow rotation room in which it is possible to rotate observers for prolonged periods. The room is a circular, windowless room 20 feet in diameter and 10 feet high without central supporting members. It has a direct motor drive and the capability of controlled angular accelerations at rates up to 15 degrees per second either in a clockwise or counterclockwise direction although in this experiment it rotated only counterclockwise. Angular velocities up to 35 rpm may be maintained with an accuracy of plus or minus one per cent. It is capable of carrying a payload of about 9000 pounds, and up to ten persons may participate in an onboard experiment. It is well instrumented and has provision for a wide variety of laboratory equipment and living facilities. The operations required in this experiment were well within the limits of the device.

All of the observations were made with observer's head 7.5 feet from the center of rotation of the room and at a velocity of approximately 11.9 rpm counterclockwise. This produced a change in the direction of resultant force of 20 degrees at the observer's head. He stood facing the direction of rotation (and for a second series opposite the direction of rotation) on a platform tilted upward 20 degrees from the floor on the outboard side of the room. As a result, when he stood erect he encountered no difficulty in standing, and the resultant force acted directly from head to feet. Thus, during rotation, he stood comfortably erect on the platform with his body weight slightly greater than normal.

The observer's task was to set a collimated, red, luminous line to the perceived horizontal. He viewed the luminous line in a self-contained apparatus mounted in a goggle which he held snuggly in position before his eyes. The apparatus consisted essentially of a luminous line which was viewed by the right eye only while the left eye was in complete darkness. The luminous line could be rotated either clockwise or counterclockwise by means of a knurled knob which was easily reached by either the observer or the experimenter. The digital readout was in degrees deviation from the horizontal axis of the device itself. The goggle was easily held in place by the observer and a flexible rubber fitting prevented light leaks under the operating conditions used. Three levels were used to monitor the alignment of the goggle apparatus, the observer's head and his body. The first level was located on the goggle itself, the second on a band over his head, and the third on his back.

METHOD

All measurements were made with observer standing with his head and body in one of five different positions with respect to gravity. After the room had been maintained at a constant velocity for one minute, the position of his head and body and the goggle were set by means of the levels. Each trial was begun by an experimenter who offset the line from the horizontal, and observer's task was merely to set it to the gravitational horizontal. Three experimenters were required for every trial. One observed the level on the observer's back to monitor his body position; a second experimenter monitored the level on the head and on the goggle and offset the luminous line before each setting; and the third made and recorded the readings. No setting was recorded unless the monitors were satisfied that the proper head and body positions were maintained within a half degree. An attempt was made to make the readings promptly in all trials because three of the positions were somewhat uncomfortable to maintain for prolonged periods. Nevertheless, observer was permitted to take as much time as he felt he needed to make an accurate setting. The light was turned off while the line was offset. The observers made five successive settings to the horizontal for each of five conditions facing forward and then five additional settings facing backward, with an interval of several hours between the two series. The five combinations of head and body position were: I. Static settings were made with observer standing on the floor with head and body erect and with the room stationary. II. Observer made settings to the visual horizontal with both head and body aligned with resultant force (RF) while he stood on the platform set at 20° and with the room rotating to produce a change of direction of RF from gravity of 20 degrees. III. This was the same as II except that the head and body were aligned with the force of gravity. IV. This was the same as II, but the body was aligned with RF while the head was aligned with gravity. V. This was also the same as II except that the body was aligned with gravity while the head was aligned with RF.

RESULTS

For the purpose of analysis, all of the data during rotation were computed as deviations from the mean of each observer's settings to gravitational horizontal under static conditions (Condition I). The mean of these static observations was considered to be his point-of-subjective-horizontal for this particular experimental situation although the deviation of the point-of-subjective-horizontal from the gravitational horizontal in each case was very small (Table I). Therefore, all of the deviations in Conditions II to V are deviations from observer's subjective horizontal using the goggle device rather than from gravity or resultant force.

An initial analysis of the data was made to determine whether the mean deviations of the settings while the observer faced forward were significantly different from those when he faced backward. Comparisons of these observations for all five conditions and for both groups of observers revealed no significant difference ($p>0.05$ or greater for all comparisons) between these two sets of observations. Consequently, the analysis of the data (Tables I and II) is made completely on the basis of the mean of the observations while observer faced forward and backward.

The combined data for the normal and L-D men and the five conditions (Table I) were subjected to a two-way analysis of variance (8) for repeated measures on the same elements, and the results are summarized in Table II. The analysis revealed no significant variation between the normal and the L-D observers, but the F was significant for the five conditions. The interaction between the two conditions was not significant, indicating that the profiles for the two groups have the same shape.

Perception of the Visual Horizontal under Static Conditions: When the data for the first and second series of observations (Condition I) were combined, the normal men showed a mean deviation of 0.7° counterclockwise from the gravitational horizontal while the L-D's had a mean deviation of only 0.2° clockwise. Neither of these differed significantly from zero ($p>0.10$ in each case). Thus, both the normals and L-D's can be said to set the line to the gravitational horizontal with this goggle device under static conditions with a very small, insignificant error.

Table I

ESTIMATE OF THE GRAVITATIONAL (CONDITION I) OR GRAVITOINERTIAL (II–V) HORIZONTAL, MADE BY SETTING A LUMINOUS LINE IN THE DARK

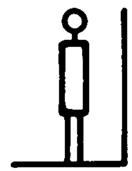
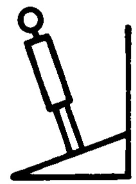
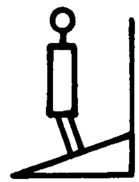
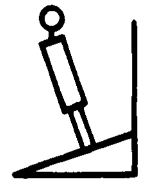
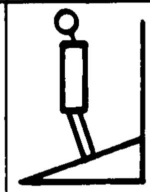
CONDITION			I	II	III	IV	V
BODY POSITION							
DEVIATION FROM GRAVITY OR RESULTANT FORCE IN DEGREES	NORMAL MEN (N=5)	MEAN	0.7	4.4	6.3	4.4	4.0
		S.D.	2.1	1.3	2.2	2.2	1.6
	L-D MEN (N=5)	MEAN	+0.2	6.6	6.8	8.5	3.8
		S.D.	1.6	3.2	2.8	2.8	2.9

Table II

Analysis of Variance Summary Table

Source of Variation	Sums of Squares	df	Mean Square	F
Between subjects	90.9	9		
A: Normal - L-D	8.6	1	8.6	1.09*
Subjects within groups	62.4	8	7.8	
Within groups	561.5	40		
B: Body position	317.8	4	79.5	11.9+
A B	28.1	4	7.0	1.0*
Subjects within groups	215.6	32	6.7	

*$p > 0.25$
+$p < 0.01$

Perception of the Visual Horizontal During Rotation: During rotation the mean settings to the perceived visual horizontal deviated systematically from the resultant horizontal for Conditions II to V. In each case (Table I) this mean setting, which varied from 4.0° to 8.5°, was between the resultant horizontal and gravitational horizontal but much closer to the former. This means that the outboard segment of the line was set below the resultant horizontal. Specifically, both the normal and the L-D observers set the luminous line clockwise from the resultant horizontal when they faced forward and counterclockwise when they faced backward. All of these deviations were statistically significant from zero (for the normals $p < 0.001$, and for the L-D's $p < 0.01$ for each comparison). It should also be noted that the L-D men showed a slightly greater variance (Table I).

An additional analysis of the significance of the difference among the various combinations of head and body position during rotation revealed that for the normal men (Table I) there were no significant differences among Conditions II to V ($p > 0.05$ for all comparisons). All of these settings deviated significantly from the static settings, but head and body position did not appear to be determining factors within the limits of this experiment. It should be noted in particular that the setting of the luminous line with head and body aligned with resultant force (Condition II) was no different from the setting when the head and body were aligned with the force of gravity in Condition III.

Similar results were found for the L-D men with two exceptions. There were no significant differences between Condition II and Conditions III to V nor between Condition III and IV ($p > 0.10$ in every case). There were, however, significant differences between Condition V and Conditions II and IV ($p < 0.01$ in each case). It should also be noted that the low mean performance of the L-D men was predominantly a result of the settings of one observer who set the line in the opposite sense from the others throughout his trials while he faced forward. It should also be noted that he had considerable difficulty maintaining the appropriate body and head positions except when he stood with head and body aligned with resultant force (Condition II).

DISCUSSION

The results of the static observations are well known (2,3,9). Both normal and L-D men made very small errors which did not differ significantly from the gravitational horizontal. It is of interest to note that the L-D's actually showed a smaller constant error and a smaller variance than the normals. The static data also show that observations with the goggle device produce results which are similar to those found with other devices used to determine the accuracy of the perception of the visual horizontal.

The results during rotation are clear-cut in showing no significant differences between normals and L-D men in setting a luminous line to the horizontal under the conditions of this experiment. The data suggest that contact information from the feet and kinesthetic information from the legs and body were adequate for the L-D observers to make the settings accurately; i.e., they were able to use the complex information available in this dynamic situation where they were required to stand erect (10,11). In the case of the normal observers, otolith information from the two head positions was integrated to produce a setting close to the resultant force. The particular role played by each sensory process is not made clear by these data. It is suggested, however, that kinesthetic cues are probably of special importance. This notion is supported by a study of the E-phenomenon under conditions of supported and unsupported tilt (12). By interpolation from the data, it was indicated that the E-phenomenon was about 3.5° for 20-degree tilts with the observer supported and that this increased to about 5.6° when he was required to maintain his own body position.

It should be emphasized that the differences between this experiment and experiments in which normal and L-D men show differences in the perception of the visual horizontal are related to the following importances in methodology:

1. In this experiment the observer actively tilted his body from the waist and his head from the shoulders rather than being passively tilted.

2. In the present experiment the observer was not supported in any way instead of being firmly supported in position.

3. The observer's feet were firmly planted on the floor which was set at the resultant horizontal rather than sitting on a seat which was set at the gravitational horizontal.

4. In the current experiment, observer viewed a collimated, luminous line of light, but he was required to hold it in his hands rather than having the device supported independently.

5. Observer perceived his body as being tilted away from the horizontal floor of the room by his own effort whereas in the typical experiment on the oculogravic illusion, he perceived the chair, floor, and his body to be tilted outboard.

6. In this study there was no pressure against the outboard side of his body as in the case of the supported, passive, apparent tilt.

The results of this experiment may be understood as a function of the complex, dynamic interaction of the many inputs from tactual receptors of the feet, kinesthetic receptors stimulated by the maintenance of bodily posture, and perhaps from other proprioceptors. In Condition III for normals, otolith information and the nonotolith information from the head and trunk were the same as in the typical experiment in which the oculogravic illusion is observed. On the other hand, for both groups kinesthetic information in maintaining bodily posture was present as were tactual cues from the feet. Transient information was available from the semicircular canals at the time observer tilted his head or body. Whereas in the situation in which the oculogravic illusion is observed there is apparent tilt of the observer, the seat, and the floor, in the present experiment the information is merely that observer has tilted his body. The frame of reference for the L-D men in this experiment was, therefore, quite different with a resulting difference in the perception of the visual horizontal. It is particularly worth noting that in Condition II where their head and body were aligned with resultant force, the point-of-subjective-horizontal was also rotated with the outboard segment downward. It is suggested that this may be explained by the fact that in this ambiguous situation, the outboard shoulder had a somewhat greater weight which was disparate with respect to the other information regarding the horizontal.

REFERENCES

1. Miller, E. F., II, Counterrolling of the human eyes produced by head tilt with respect to gravity. Acta otolaryng., Stockh., 54:479-501, 1961.

2. Graybiel, A., Oculogravic illusion. Arch. Ophthal., 48:605-615, 1952.

3. Graybiel, A., and Clark, B., The validity of the oculogravic illusion as a specific indicator of otolith function. Aerospace Med., 36:1173-1181, 1965.

4. Guedry, F. E., Jr., Psychophysiological studies of vestibular function. In: Neff, W. D. (Ed.), Contributions to Sensory Physiology. Vol. 1. New York: Academic Press, 1965. Pp 63-135.

5. Clark, B., and Graybiel, A., Perception of the visual horizontal in normal and labyrinthine defective subjects during prolonged rotation. Amer. J. Psychol., in press, 1966.

6. McLeod, M. E., and Meek, J. C., A threshold caloric test: Results in normal subjects. NSAM-834. NASA Order R-47. Pensacola, Fla.: Naval School of Aviation Medicine, 1962.

7. Graybiel, A., and Fregly, A. R., A new quantitative ataxia test battery. Acta otolaryng., Stockh., 61:292-312, 1966.

8. Winer, B. J., Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

9. Neal, E., Visual localization of the vertical. Amer. J. Psychol., 37:287-291, 1926.

10. Jones, G. M., and Milsum, J. H., Spatial and dynamic aspects of visual fixation. IEEE Trans. Bio-Med. Engineering, BME-12, 54-62, 1965.

11. Schöne, H., On the role of gravity in human spatial orientation. Aerospace Med., 35:767-772, 1964.

12. Werner, H., Wapner, S., and Chandler, K. A., Experiments on sensory tonic field theory of perception: II. Effect of supported and unsupported tilt of the body on the visual perception of verticality. J. exp. Psychol., 42:346-350, 1951.

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The purpose of this experiment was to study the influence of otolith and nonotolith information in the perception of the visual horizontal during rotation. Five normal men and five men with defective labyrinthine function acted as observers. All measurements were made in a room which could be rotated. Initial, static measurements were made while the men stood erect in the stationary room. Similar measurements were made during rotation while the observer stood on a platform set to the resultant horizontal with head and body aligned with resultant force. Data were also obtained with three other combinations of head and body position. This procedure was designed to produce two situations for the normal men in which otolith and nonotolith information were synergistic and three others in which they were antagonistic. The results showed that the perception of the visual horizontal during rotation in this situation is quite different from that found when the observer is rigidly supported in a chair during rotation. Settings to the visual horizontal during rotation were not systematically related to differences in head and body position nor were there significant differences between the normal and L-D men. The results show that nonotolith information predominates in this experimental situation. Furthermore, the data suggest that the spatial orientation of a pilot strapped in a cockpit may be somewhat different from his spatial orientation when he is standing on a rotating space platform.

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Synergistic cues						
Antagonistic cues						
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