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Abstract

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ADAPTATION OF STEREO VERTICAL AS A FUNCTION OF PROLONGED BODY TILT IN THE SAGITTAL PLANE

by

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requirements for the degree
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Approved by the Faculty,

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the Degree Doctor of Optometry.

Colin Pitblado

Director of Thesis

EXPERIMENT NUMBER ONE

INTRODUCTION

Without the benefit of monocular cues to depth perception, judgements of perceived orientation of objects in visual space have been shown to be dependent upon the three primary determinants: Eye position, relative head-to-body position, and relative body position to gravity. It is well documented throughout the literature that under controlled conditions each of the three relationships can be the principle determinant for judgement of orientation. Many of these studies use subjective placement of a vertical luminous line as the basis of their investigation.

The positioning of a vertical line has been used in a variety of studies concerned with visual perception in all three of the major planes, the mid-frontal plane (coronal plane), the mid-transverse plane (horizontal plane), and the median plane (sagittal plane).[1] Much of the work in this area has been done with the line placement in the coronal plane, such as the studies of the "A" and "E" effects on perceptual judgements. Few investigations have been done with line placement in the sagittal plane, this being the plane with which we are primarily concerned.

According to the Gosnell-Miller study, subjects made errors (less than 4°) in judgement of a gravitational vertical test line in the median plane when tilted back on a tilt-table.[2] They found no significant relationship between the degree of error and the degree of body tilt; however, adaptation effects were not considered.

The purpose of our study was to first determine if adaptation occurs to prolonged body tilt with respect to the vertical placement of a luminous line in the median plane. Next, if adaptation did occur, which primary determinant or combination was most likely responsible? Pitblado, in a similar investigation, studied adaptation effects of vertical line placement with respect to forward head tilt, but to our knowledge, our particular study has not been done.[3] We selected a 45° angle of body tilt for our study.

We first predicted that adaptation would occur with body tilt of 45° and placement of the gravitationally-vertical line should gradually drift in the direction parallel to that of the body. Secondly, we postulated that should adaptation occur, it was due to the tactile-pressure senses of the body, the tactile-pressure senses being those receptors providing information as to body weight distribution, skin pressure, etc. These receptors, in addition to those of the inner ear, are responsible for detection of body position relative to gravity. The primary determinants of visual space whose values differed from those in the upright position were those which sense the relationship of body to gravity. Together, the tactile-pressure senses and otolith senses of the inner ear provide this information. However, according to Wade (1970), the otolith system does not adapt, leaving only the tactile-pressure system responsible for this adaptation.[4]

Apparatus

The apparatus as used in this study was also used in the Gosnell-Miller study, and is described here as follows:[2]

A tilt-table (78" X 30") was constructed, permitting the subjects to be tilted backwards in the median plane. It was covered with a 3" thick slab of polyfoam and was fitted with a footrest and adjustable headrest. The headrest was constructed such that it restrained the subject's head in a straight ahead position. The headrest was adjustable in the mid-frontal (coronal) plane to maintain the head in its normal position relative to the neck and trunk. It was also adjustable vertically to accommodate various subjects over a height range from 4 ft. 8 in. to 6 ft. 4 in.

The table could be swung through an arc of 100° and could be locked in seven positions, varying in 15° increments from 0° (standing perpendicular to the floor) to 90° (supine). The positioning was such that the exact angle of tilt could be reproduced from subject to subject. In the 0° position the subject stood on the footrest which was 12" wide and parallel to the floor. A safety strap was installed on the table for the subject's security and to minimize body movement during the testing sequence.

The test target was a bright luminous line 25" long and 0.03" wide. This was achieved by two 12-volt, 1.5 amp bulbs contained in a "black box" which had an opaque glass cover. The test line was formed by scribing the glass cover to make it translucent. The light emitted from the target was insufficient to make any of the apparatus visible to the subject.

A scale marked in degree increments was attached to the center of rotation of the target, and a pointer indicated in degrees the angle of the target. This scale could easily be read to an accuracy of $\pm 0.5°$. The perpendicularity of the illuminated line was checked after preliminary adjustments had been made. The target was recalibrated in the 0° position before testing each subject.

Subjects

Twenty male subjects, ranging in age from 22 to 35, were tested. The subjects were randomly selected and screened for a minimum of 80% stereopsis as measured by the Keystone multistereo card, PP-10 (S-2). Those requiring lens corrections wore them during the test sequence.

Procedure

The subject was brought into the testing room, and the necessary measurements required for adjustment of the apparatus were taken. One experimenter made the appropriate adjustments while the other tested the subject for stereopsis. Those subjects exhibiting less than 80% were excused from further testing, and the procedure was started over for the next subject.

After passing the stereopsis test, the subject was positioned on a tilt-table by means of a restraining headrest and a waist strap. The subject was then given the following information and instructions:

"We want you to say 'now' when the luminous line in front of you appears to be vertical; that is, perpendicular to the floor. We will start each judgement from a pre-set position with the top either toward you or away from you and slowly move it toward the vertical position." This procedure was then demonstrated with the room lights still on.[2]

The subject was also instructed to close his eyes after every response while we checked the degree of tilt with a penlight. He was then to open his eyes and make another judgement when we were ready and instructed him to "open." The subject was instructed to keep his eyes closed during the whole experiment except when making judgements, as a further precaution against bias effects from looking at the luminous line in its resting position.

No further information or instructions were given to the subject during the testing sequence. He was not allowed any feedback as to the accuracy of his judgements. Any questions asked concerning the apparatus or test were deferred until completion of the test sequence.

Following the pre-test instructions, the room lights were turned off and the test sequence commenced. To prevent portions of the apparatus from becoming visible to the subject with dark adaptation, the intensity of the luminous line was maintained just above threshold. The method of adjustment was used with an equal number of preset positions toward and away. The line was moved toward the objective vertical at a steady velocity of approximately 2° per second by the experimenter from randomized preset positions from 5° to 20°.[2]

Four findings were taken at three-minute intervals for 30 minutes, the subject being positioned at a 45° angle during the entire experiment.

RESULTS

Table One shows the amount of adaptation in degrees that occurred over the thirty-minute period. Positive values are judgements made when the bottom of the luminous line is closer to the subject in reference to the vertical plane and the top of the line is further from the subject.

Of the 20 subjects, 17 showed adaptation in the positive direction. Only three subjects showed adaptation in the negative direction. Utilizing a computer, we ran a "t" test on the amount of adaptation. The value of "t" was 3.93, whose probability is less than .01 for a 2-tailed test. This shows that there was a statistically significant amount of adaptation in the positive direction of judgements. The mean adaptation was +6.35°, with a standard deviation of 7.22°

Figure #1 shows the amount of adaptation that occurred. At each three-minute interval the group data is averaged and plotted. The total average amount of adaptation that occurred at the end was +6.34°.

DISCUSSION

Initially we predicted that adaptation would occur from prolonged body tilt. Our results agree with this hypothesis, and the adaptation was quite significant. We further predicted adaptation in the negative direction; however, our results show just the opposite. Adaptation occurred in the positive direction. Because the direction of adaptation was not in the direction of kinesthesis, this provides a clue as to how the otolith and tactile-pressure senses may be separated experimentally.

EXPERIMENT NUMBER TWO

INTRODUCTION

To resolve the question posed by the first study and to attempt to single out the sensory mechanism responsible for this adaptation, a short pilot study was conducted. We hoped to provide an indication as to whether the unexpected adaptation reported was due, at least in part, to adaptation in the otolith system. This was to be accomplished by changing the mechanisms stimulated while keeping the experimental conditions as nearly identical to the initial study as possible.

In the particular design that we chose, the stimulation of the tactile-pressure receptors was eliminated or reduced to minimum while stimulation of the otolith system was maintained as in the initial study. However, in making these adjustments, kinesthetic stimulation would be introduced. As indicated, kinesthetic adaptation effects are directly opposite that shown in our initial study. This was particularly evident in the Pitblado paper referred to previously. Under kinesthetic adaption effects over time, one should tend to place a vertical line more toward parallelism with the facial plane.[3]

From the results of the initial study, we made predictions as to the outcome of the pilot study. With tactile-pressure mechanisms removed any effect in the same direction as that in Experiment #1 should be attributable to adaptation of the otolith mechanism. Understandably, there could be a substantial change in the magnitudes of adaptation due to the variables introduced. These variables being the removal of tactile-pressure stimulation and the addition of kinesthetic stimulation.

The effects produced by kinesthetic adaptation would tend to reduce or mask those effects contributed by the otolith. Effects of removing the stimulation to the tactile-pressure receptors is not well understood; so that insignificant changes reported in this study would be inconclusive as to the system primarily responsible for the adaptation in the initial study. However, significant change of line placement in the direction predicted would provide good support for the hypothesis of otolith adaptation due to the reverse adaptation effects of kinesthesis.

Apparatus

The tilt-table was used in the vertical position only. Subjects stood about one foot in front of the table such that the pivot point of the luminous line was directly along the line of sight at approximately 20 - 24 inches from the subject's visual plane. This was to maintain the same relationship as in the initial study.

A head and chinrest firmly held the subject's head in position, 45° back from the vertical. This head and chinrest assembly was quite crudely arranged, but upon adjustment was most adequate to maintain the proper head position. The head and chinrest used was very similar to that of a Keratometer and various other ophthalmic instruments with three contact points, two on the forehead and one to firmly hold the chin in place. The foam headrest from the table, when properly positioned, was used to support the back of the head and neck, holding the subject's head firmly in the head and chinrest. Therefore, the subject was positioned such that his body was perpendicular to the floor with the head tilted back 45° and the luminous line located along the visual axis.

Procedure

This procedure was similar to that of the initial study except that the subjects were tested in two-minute intervals instead of three, and the entire test sequence involved ten minutes rather than thirty. This was primarily due to the discomfort caused by long-term maintenance of this body position. The subject's posture and head position were as discussed with the apparatus; body vertical with head tilted back 45°. Instructions, stimulus presentation, and response conditions were all the same as in the initial study. Five of the subjects in the initial study were also used for subjects in the pilot study and were selected due to large adaptation exhibited on the initial study.

RESULTS

Table One shows us the amount of adaptation that occurred for the head tilt at the ten-minute interval. Four of the subjects showed adaptation in the positive direction with one subject showing no adaptation. We ran a "t" test on the amount of adaptation, resulting in a "t" value of 2.09, which indicates that the results were statistically significant at the .05 level for a one-tailed test. The mean adaptation was 3.65° with a standard deviation of 3.89°.

Since the subjects were first run in the initial study, we compared the data of these subjects separately for each study. Table One shows the amount of adaptation for the same five subjects in the initial study at the nine-minute interval. The "t" test run on this data resulted in a "t" score of 4.48, which indicated that the results were statistically significant at the .01 level for a two-tailed test. The mean was 8.00° with a standard deviation of 3.98°.

Figure #2 shows the amount of adaptation that occurred for the five subjects plotted separately for each experiment. Experiment #1 was plotted at three-minute intervals, and Experiment #2 plotted at two-minute intervals.

DISCUSSION

The results show that adaptation did occur in the same direction as the initial study, strongly suggesting that the otolith system of the inner ear does adapt over time. This is the first behavioral study to our knowledge indicating adaptation of the otolith system. This supports the work of Adrian in which, neurophysiologically, impulses from the otolith system were altered systematically over time.[5] However, our conclusions differ markedly from those of Wade in his paper referred to previously.

There are several possible explanations as to the disagreement between our results and that of Wade. Whereas our study was exclusively concerned with tilt effects in the median plane, Wade was concerned primarily with tilt effects in the mid-frontal or coronal plane. Not much is known as to the significance of this variable. Probably, the key to the opposing conclusions are the varied time factors involved. Wade's investigation involved very short time intervals of no more than three minutes.

As previously discussed, the kinesthetic system adapts completely in several minutes; however, results of our initial study show adaptation to occur over much larger periods of time. Providing that the otolith system adapts in the opposite direction as the kinesthetic system, as we have concluded, for very short durations of body tilt, the kinesthetic system may mask-out the effects of the otolith. Therefore, under the conditions of the Wade study, we feel the observations reported are not necessarily incompatible with the results of our investigation.

Additional studies in this area are necessary to clear up the specific adaptation effects provided by the otolith system and tactile-pressure receptors. Further research that we would like to suggest include:

(1) The experiment replicated with many more subjects, and for longer periods of time.

(2) Determine the effects of Experiment #2 with the body vertical and the head fixed in the primary position of gaze.

(3) Similar studies undertaken using subjects with non-functioning otolith systems.

BIBLIOGRAPHY

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[1]Howard, I. P., and Templeton, W. B. Human Spatial Orientation. London: John Wiley & Sons, 1966.

[2]Gosnell, M., and Miller, T. M. :Effect of Body Tilt on the Constancy of the Stereo Vertical." Unpublished thesis, Pacific University, College of Optometry, May, 1970.

[3]Pitblado, Colin B. "Rotation of the Apparent Stereoscopic Vertical Following Induced Tilting of the Head." Unpublished manuscript presented at the meeting of the West Coast Study Group on Human Vision, Pacific University, April, 1970.

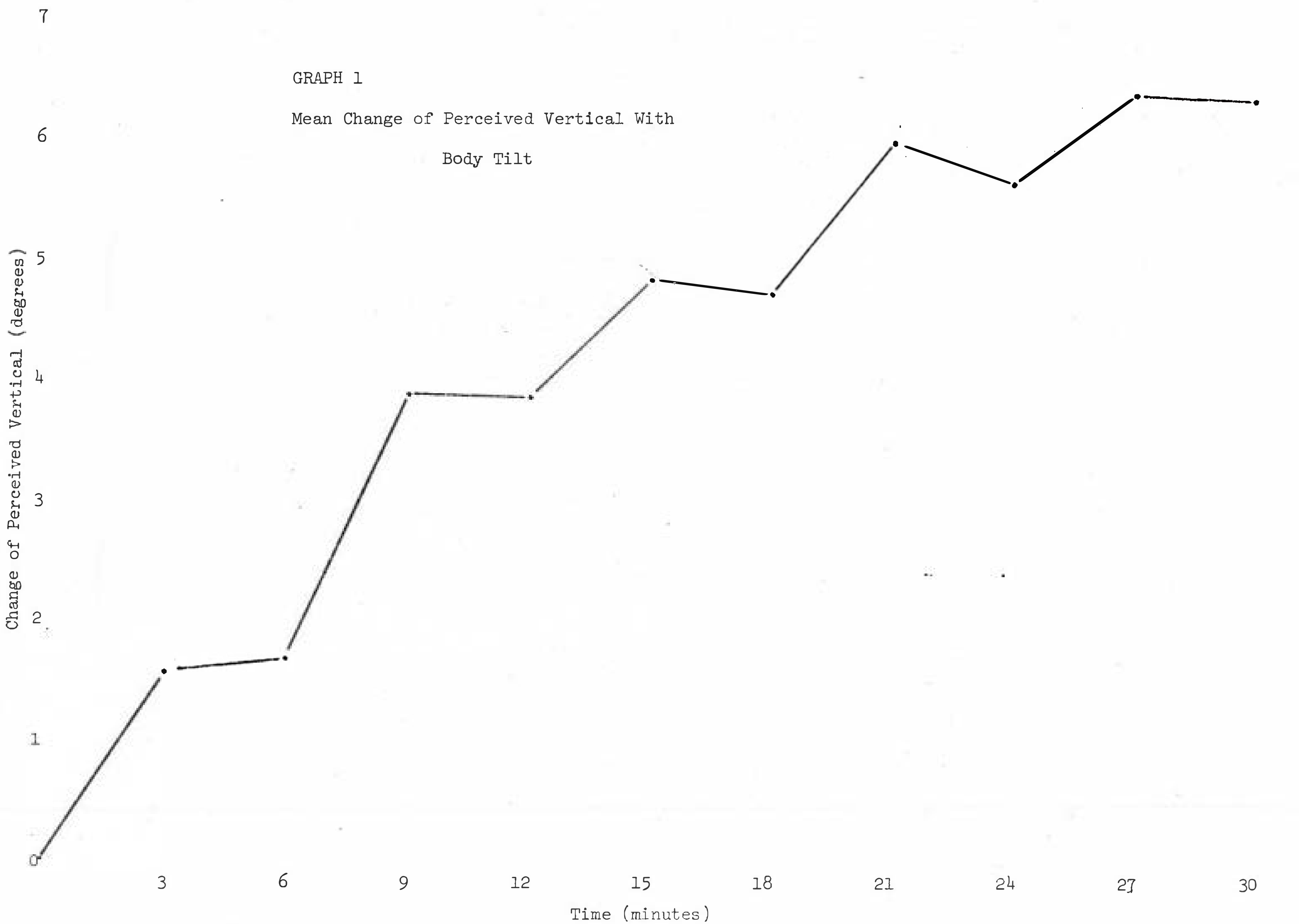
[4]Wade, N. J. "Effect of Prolonged Tilt on Visual Orientation." Quarterly Journal of Experimental Psychology, Vol. 22, 423-439, 1970.

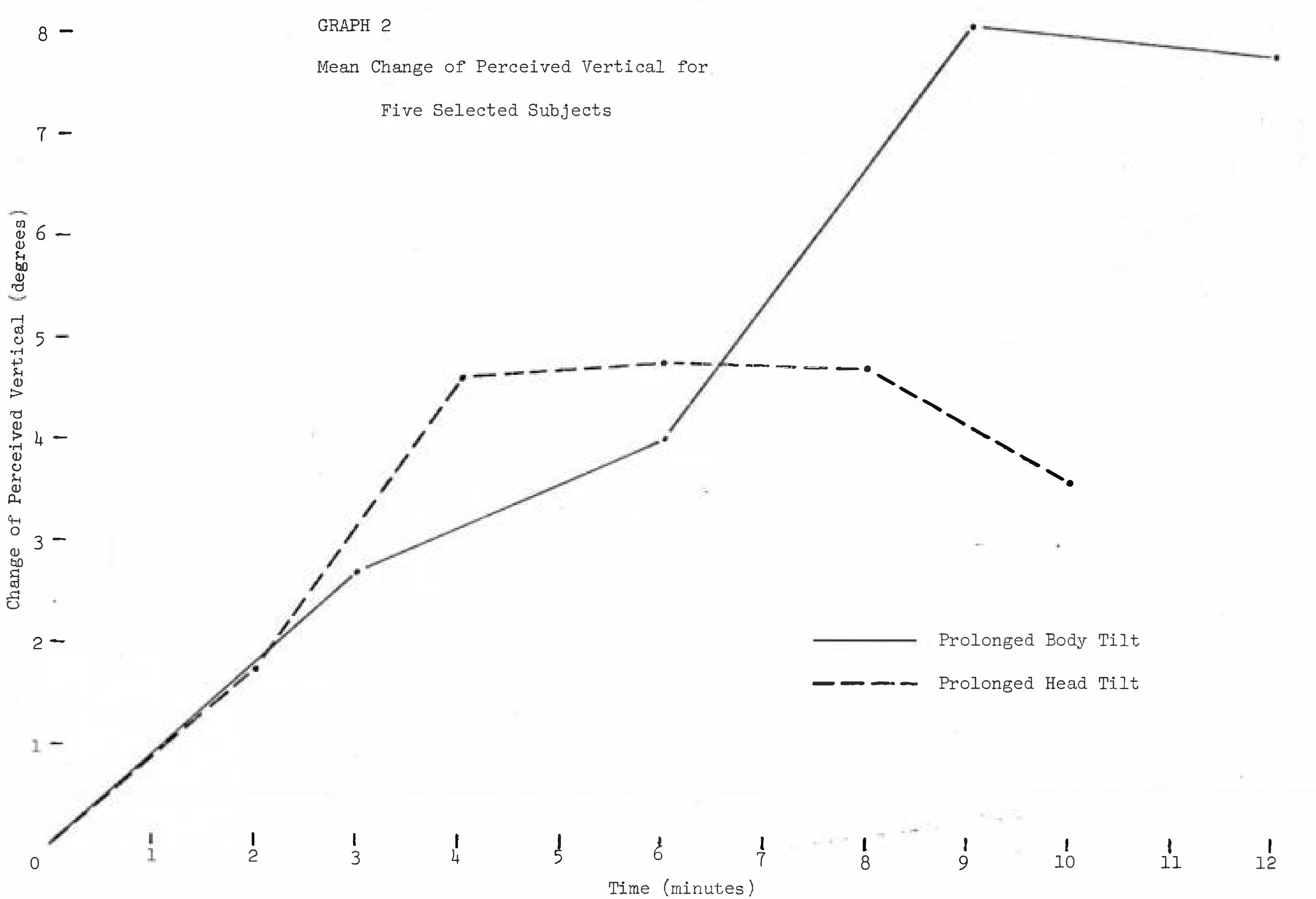
[5]Adrian, E. O. "Discharges from Vestibular Receptors in the Cat." Journal of Physiology, Vol. 101, 389-407, 1943.

APPENDIX

TABLE 1

	Body Tilt		Head Tilt
	30 min	9 min	10 min
GN	+16.25	+11.75	+10.00
CP	+ 7.5	+ 2.75	+ 1.25
SF	+18.25	+12.25	+ 4.25
MS	+14.75	+ 6.5	0.0
KB	+16.00	+ 6.5	+ .25
JD	+ 5.5		
GG	+ 6.75		
EM	+11.00		
BD	- 1.00		
DH	+ 2.5		
DE	+ 6.75		
BP	- 4.0		
MM	+11.75		
BS	+ .50		
JM	+ .50		
HB	+ 8.25		
DH	+ 1.75		
LP	- 9.0		
BM	+10.25		
DR	+ 2.75		


GRAPH 1
Mean Change of Perceived Vertical With
Body Tilt
Change of Perceived Vertical (degrees)
7
6
5
4
3
2
1
0
3
6
9
12
15
18
21
24
27
30
Time (minutes)



GRAPH 2
Mean Change of Perceived Vertical for
Five Selected Subjects
Change of Perceived Vertical (degrees)
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Time (minutes)
Prolonged Body Tilt
Prolonged Head Tilt

Raw Data for Prolonged Body Tilt

(Mean of four judgements)

Time (minutes)

	0	3	6	9	12	15	18	21	24	27	30
GN	145.5	153.75	155.75	157.25	160.5	160.75	161.5	159.5	159.75	160.75	161.75
CP	124	127.5	125.0	126.75	128.75	129.25	130.0	133.0	134.0	130.75	131.5
SF	116.0	107.25	113.75	128.25	124.25	127.5	128.5	128.75	129.0	135.0	134.25
JD	144.25	144.0	144.0	142.5	148.25	146.75	147.0	154.0	151.5	155.0	149.75
GG	119.25	124.5	125.25	124.75	124.75	124.0	126.0	131.0	130.0	125.5	126.0
EM	134.0	139.25	143.0	139.25	139.50	141.0	142.25	140.0	142.0	143.5	145.0
BD	128.0	127.25	128.75	130.75	130.0	130.0	128.75	128.25	127.25	127.0	127.0
DH	128.0	125.25	126.0	126.75	125.75	128.5	128.0	129.75	127.75	128.25	130.5
DE	128.75	134.0	133.25	139.5	134.75	138.25	134.75	133.0	133.5	137.5	135.5
BP	129.25	128.75	126.0	125.0	126.0	128.75	120.0	126.5	124.25	123.5	125.25
MM	130.5	126.5	127.5	142.0	138.5	141.75	139.5	138.5	136.5	139.5	142.25
BS	128.5	129.5	131.0	131.75	133.0	130.0	130.25	130.75	131.75	132.0	128.75
KB	134.5	135.5	137.0	141.25	141.0	144.5	146.5	146.75	149.5	147.5	150.5
JM	133.25	134.5	135.75	134.25	132.75	134.25	131.0	133.25	137.0	134.0	133.75
MS	130.25	139.5	138.75	136.75	135.0	135.5	139.5	139.5	139.75	145.5	145.0
HB	135.5	136.25	139.0	137.75	139.5	139.25	142.0	140.5	140.0	143.75	143.75
DH	132.0	135.25	130.5	131.5	134.5	134.25	133.25	135.25	134.75	132.0	133.75
LP	133.75	128.75	133.0	132.75	128.25	127.75	131.75	127.75	126.0	126.75	124.75
BM	133.0	136.75	136.75	138.5	141.25	144.5	141.0	144.0	141.75	140.75	143.25
DR	130.0	131.25	125.75	128.5	128.5	128.25	130.75	130.75	134.75	130.5	132.75
$\bar{X}$	130.41	132.47	132.57	134.78	134.73	135.73	136.61	136.87	136.53	137.28	137.25
Diff	0	1.56	1.66	3.87	3.82	4.82	4.70	5.96	5.62	6.37	6.34
Range	121.55 116.0	153.75 107.25	155.75 113.75	157.25 124.75	160.5 124.25	160.75 124.0	161.5 120.0	159.5 126.5	159.75 124.25	160.75 123.5	161.75 124.75

Raw Data of Prolonged Head Tilt

(Mean of four judgements)

	0	2 min	4 min	6 min	8 min	10 min
GN	95	100	104	103.5	109.5	.05.0
CP	94	93.5	94.5	95	95.75	95.25
SF	93.25	95.25	99.25	100.0	97.0	97.5
MS	94.5	92.5	97.25	97.0	95.5	94.5
KB	94.5	98.5	99.25	99.5	97.0	96.75
$\bar{x}$	94.25	95.95	98.85	99.0	98.95	97.80
Mean Diff.	0	1.70	4.60	4.75	4.70	3.55
Range	95.0	100.0	104.0	103.5	109.5	105.0
	93.25	92.5	94.5	95.0	95.5	94.5

Prolonged Body Tilt

Data from the same five subjects above as taken from raw data of Experiment 1.

	0	3 min	6 min	9 min	12 min
$\bar{x}$	130.05	132.70	134.05	138.05	137.90
Mean Diff	0	2.65	4.0	8.0	7.85
Range	145.5	153.75	155.75	157.25	160.5
	116.0	107.25	113.75	126.75	124.25