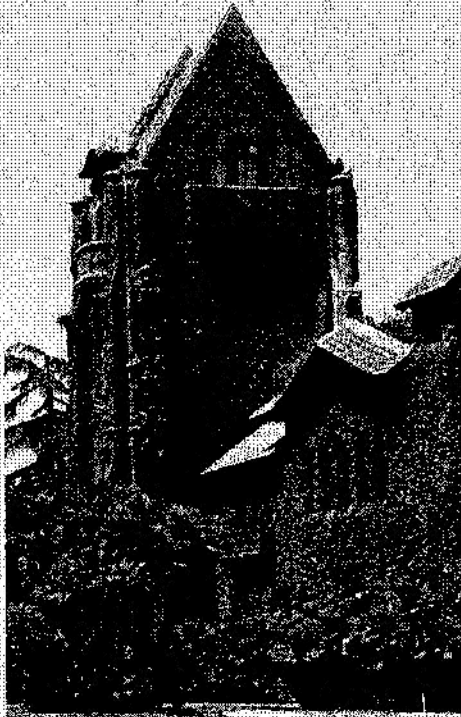


San Jose State College



FACTORS INFLUENCING THE PERCEPTION OF ANGULAR ACCELERATION IN MAN

Principal Investigator: Brant Clark

August 1968

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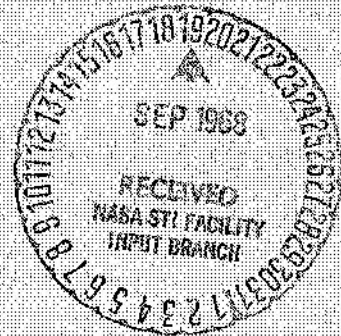
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INTRODUCTION

This cooperative research project has been conducted as a collaborative research effort between the Psychology Department of San Jose State College and Ames Research Center. Specifically, the research has been carried out in close collaboration with John D. Stewart of the Man-Machine Integration Branch. The development of the Man-Carrying Rotation Device has made possible studies of the perception of rotation under very carefully controlled conditions. It was the purpose of this cooperative research effort to exploit the capability of the MCRD to produce precise angular accelerations for varied intervals of time using the methods which have been developed at Ames Research Center to investigate the perception of rotation in man. The individuals carrying out this work were the principal investigator and Mr. Stewart assisted by three research assistants who are candidates for the master's degree in Psychology at San Jose State College. These are Richard L. Doty, Richard D. Parsons, and Steven L. Dockstader. Mr. Dockstader replaced Mr. Doty in July when Mr. Doty left to undertake graduate work for the Ph.D. in Psychology at Michigan State University.

PURPOSES OF THE RESEARCH

The Perception of Rotation in Normal Men

The objective of this research was to investigate the nature of the perception of angular acceleration in normal men during and following rotation. Whereas the majority of the earlier studies have been primarily concerned with physical models and the physiological mechanisms of the semicircular canals, this project has been concerned with man's subjective reactions to angular acceleration. Using the MCRD and a psychophysical method developed at Ames Research Center, work has been carried out to determine the range of sensitivity for angular acceleration in normal men. In addition, the effects of duration of stimulation, presence of visual targets in the field, axis of rotation and suprathreshold stimulation by angular acceleration have been studied. The work has resulted in reports at two meetings; two studies are in the final stages of data collection and preparation of the reports is well advanced; and one thesis study is complete and submitted for publication while the other is in the final stage of writing. The following summary of work completed and in final stages of completion will indicate the degree to which our objectives have been achieved.

SUMMARIES OF RESEARCH FINDINGS

1. Thresholds for the perception of angular acceleration determined in a precision rotation device. Clark, B., & Stewart, J.D. A paper presented at the annual meeting of the Aerospace Medical Association, Miami, Florida, May 6-9, 1968.

Summary

The purpose of this study was to determine the sensitivity of normal men to angular acceleration using the Ames Man-Carrying Rotation Device (MCRD). The MCRD is a one-degree-of-freedom simulator which rotates about a vertical axis up to 45 rpm with continuous angular acceleration variations up to $30^{\circ}/\text{sec}^2$. The accelerations can be programmed and measured in $0.01^{\circ}/\text{sec}^2$ steps with rise times of the order of 0.1 sec. The MCRD is essentially free of vibrations perceived by the observer at the low velocities used, and he is unable to detect when he accelerates through zero velocity. The observer sat erect in darkness at the center of rotation and reported the direction of rotation for angular accelerations of 10 sec. duration. Accelerations were presented using a forced choice random, double staircase method. This procedure determined thresholds with velocities which rarely exceeded 2-3 rpm. Thresholds, were computed following a method which earlier studies have shown to be reliable and valid under the conditions used. Thresholds obtained on 33 normal men were found to vary between 0.05° and $2.20^{\circ}/\text{sec}^2$ with a mean of $0.42^{\circ}/\text{sec}^2$ and are lower than those found in most earlier studies (Figure 1). These data show that normal men are extremely sensitive to angular accelerations applied to their bodies. This information when it is veridical can be a contributing factor in controlling aircraft. On the other hand when the information is not veridical, it may contribute to disorientation.

RANGE = 0.05 - 2.20°/sec² S.D. = 0.40°/sec²

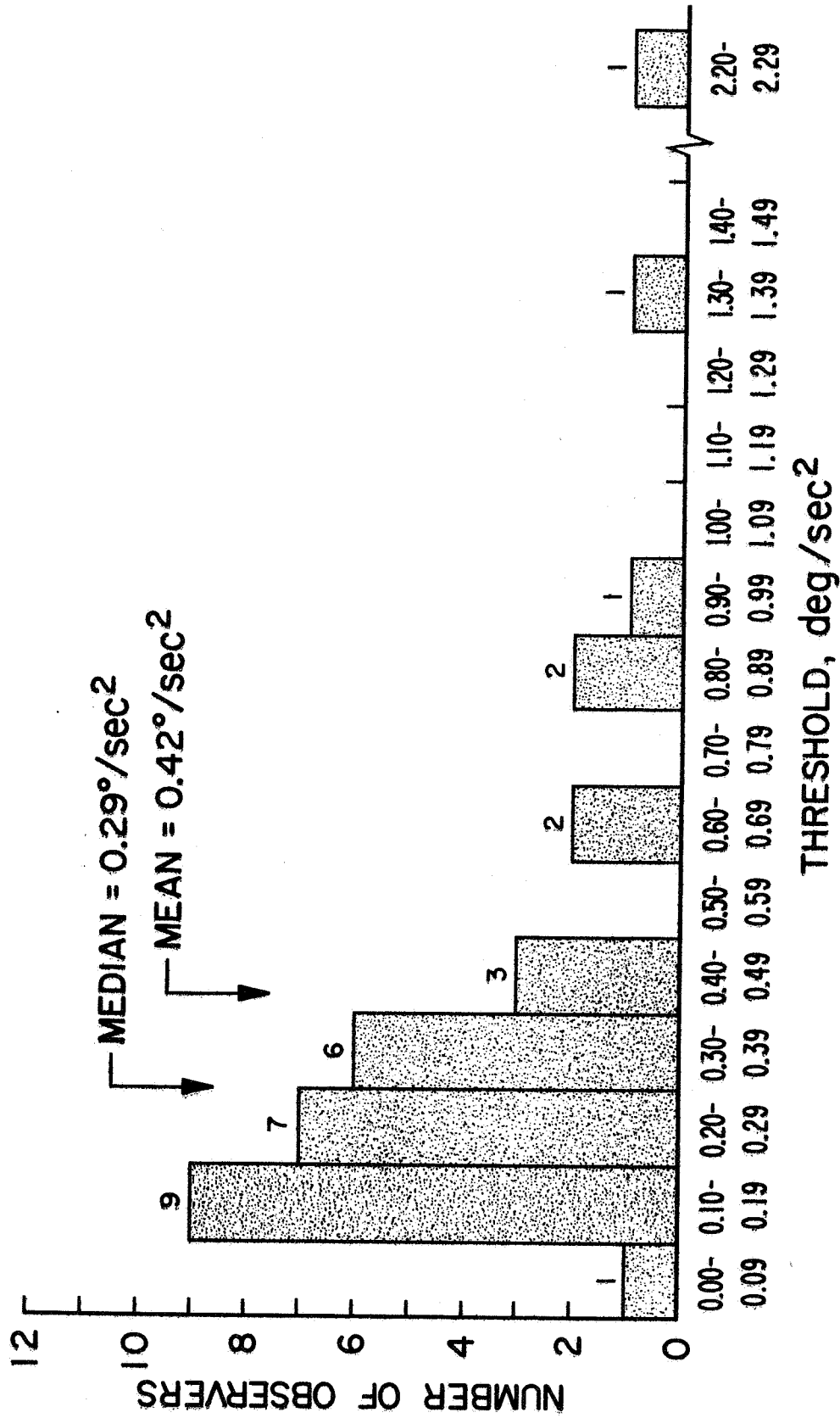


Figure 1. Distribution of thresholds for the perception of angular acceleration for 33 normal men (Clark & Stewart, 1968).

2. Some recent studies on the perception of rotation. Clark, B.
A paper presented at the meeting of the Bárány Society, Uppsala, Sweden,
May 29-30, 1968. (This paper will be published in the proceedings of
the meeting.)

Summary

The purpose of this paper was to give a summary of recent work carried out at Ames Research Center using the MCRD to rotate the observers. The paper did three things. It described the MCRD, presented results of our threshold studies, and summarized some of our work on the effects of prolonged accelerations on normal men. These studies of the perception of rotation give support to earlier studies which have shown that the perception of rotation is a highly complex process. The data show that the perception of rotation is dependent upon the interaction of complex transducer mechanisms in the receptors as well as highly complex central nervous system processes. The data on thresholds suggest that normal men are even more sensitive to angular acceleration under optimum testing conditions than earlier studies had shown. This is particularly true when the oculogyral illusion is used as the indicator of sensitivity. The studies of prolonged acceleration described the complete cycle of response increase and decline during prolonged constant acceleration and an aftereffect having a similar pattern which occurred when the acceleration was reduced to zero. Highly complex effects occurred during the constantly increasing accelerations notably a waxing and waning of the perception of rotation. These results have significance in relation to a general theory of vestibular function.

3. The effect of duration of stimulus presentation upon the angular acceleration threshold of man. Doty, R.L. Thesis, Department of Psychology, San Jose State College, June 1968. (A shorter version has been submitted for publication.)

Summary

This study is concerned with the effects of the duration of angular acceleration on man's sensitivity to rotation as indicated by his perception of the oculogyral illusion. It is also concerned with the stimulus as a product of acceleration x time in producing vestibular effects. In order to investigate these problems, oculogyral illusion thresholds for 10 men were determined in the Ames MCRD. Thresholds were measured for stimulus durations of 0.50, 1.00, 1.50, 3.00, and 6.00 sec. by a random, double staircase procedure. Mean oculogyral illusion thresholds ranged from 0.10° to $0.62^{\circ}/\text{sec}^2$ and varied inversely with the duration of the stimulus (Figure 2). The product of acceleration times duration of angular acceleration was found to be a significant increasing linear function of the duration of the stimulus within the limits of the durations used and not constant as earlier data suggest.

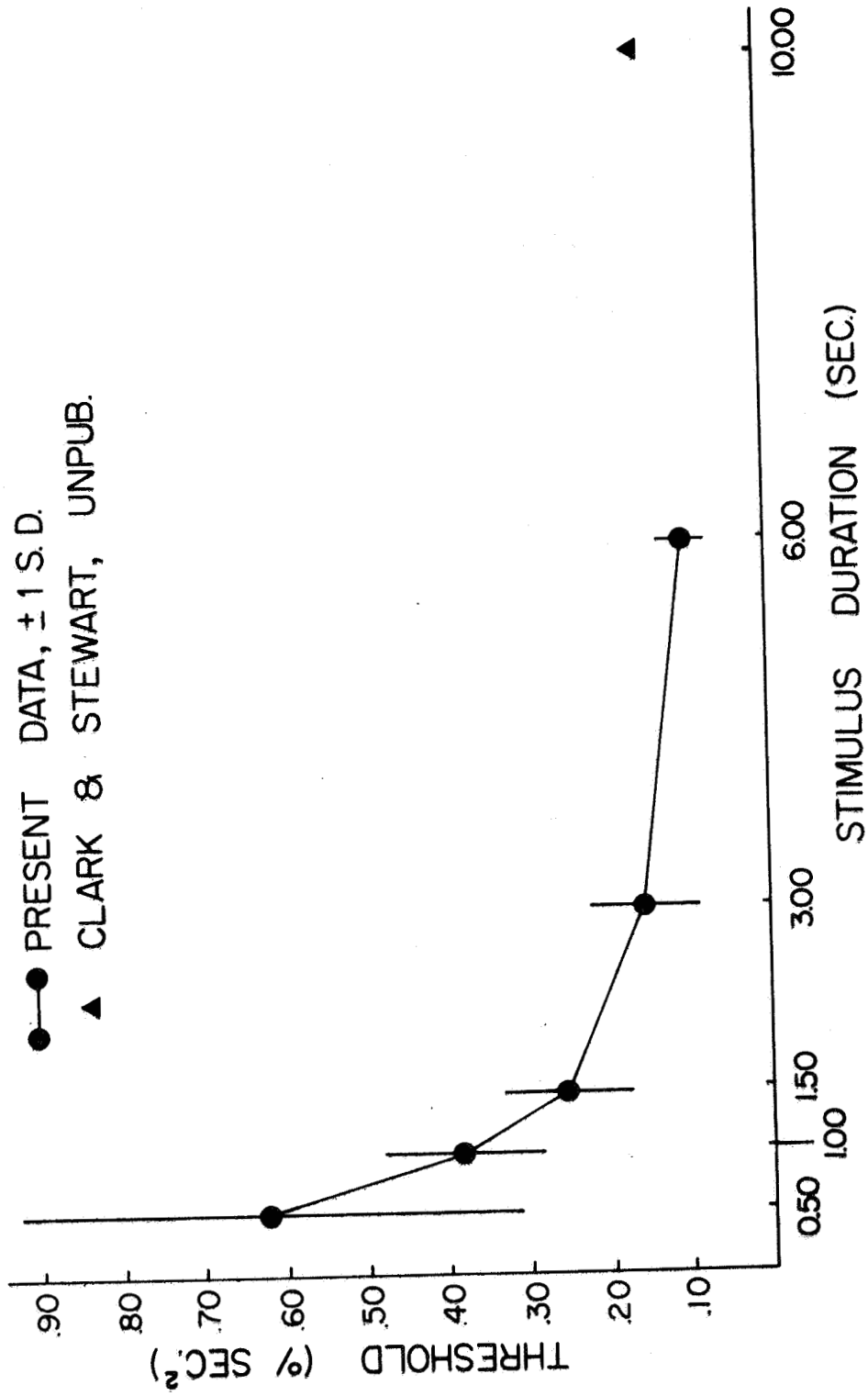


Figure 2. Oculogyral illusion thresholds for 10 normal men as a function of stimulus duration (Doty, 1968).

4. Magnitude estimates of the oculogyral illusion during and following angular acceleration. Parsons, R.D. Thesis, San Jose State College, August 1968.

Summary

This experiment investigated the influence of rotation on normal men using the illusory motion of a visual target in darkness to indicate the effect. Suprathreshold angular accelerations of several magnitudes and durations were used as the stimuli to produce the oculogyral illusion, a visual-vestibular phenomenon. Ten observers gave magnitude estimates of the oculogyral illusion while they were rotated in the MCRD to produce angular accelerations about the vertical axis of the head. A factorial design consisting of four constant angular accelerations (2° , 3° , 6° , and $9^{\circ}/\text{sec}^2$) and four times (1, 3, 6, and 9 sec.) was used, and additional trials of constant velocity served as a control for visual autokinesis. Magnitude estimates, averaged across replications and observers, were plotted against time to form group curves. Analyses of variance were also performed on first effect and aftereffect measures. Systematic changes in magnitude estimates were revealed both during and following all accelerations (Figure 3). The maximum magnitude estimates of the first effect and aftereffect were found to vary directly with both duration and intensity of acceleration. Duration of the first effect varied directly with intensity, and duration of the aftereffect varied directly with both intensity and duration of acceleration. It was also found that equal products of acceleration and time produced close similarities for certain measures of behavioral effects. The weight of evidence from the data was found to be inconsistent with a simple torsion-pendulum model of semicircular canal functioning, and it was suggested that the discrepancies were due to central processes.

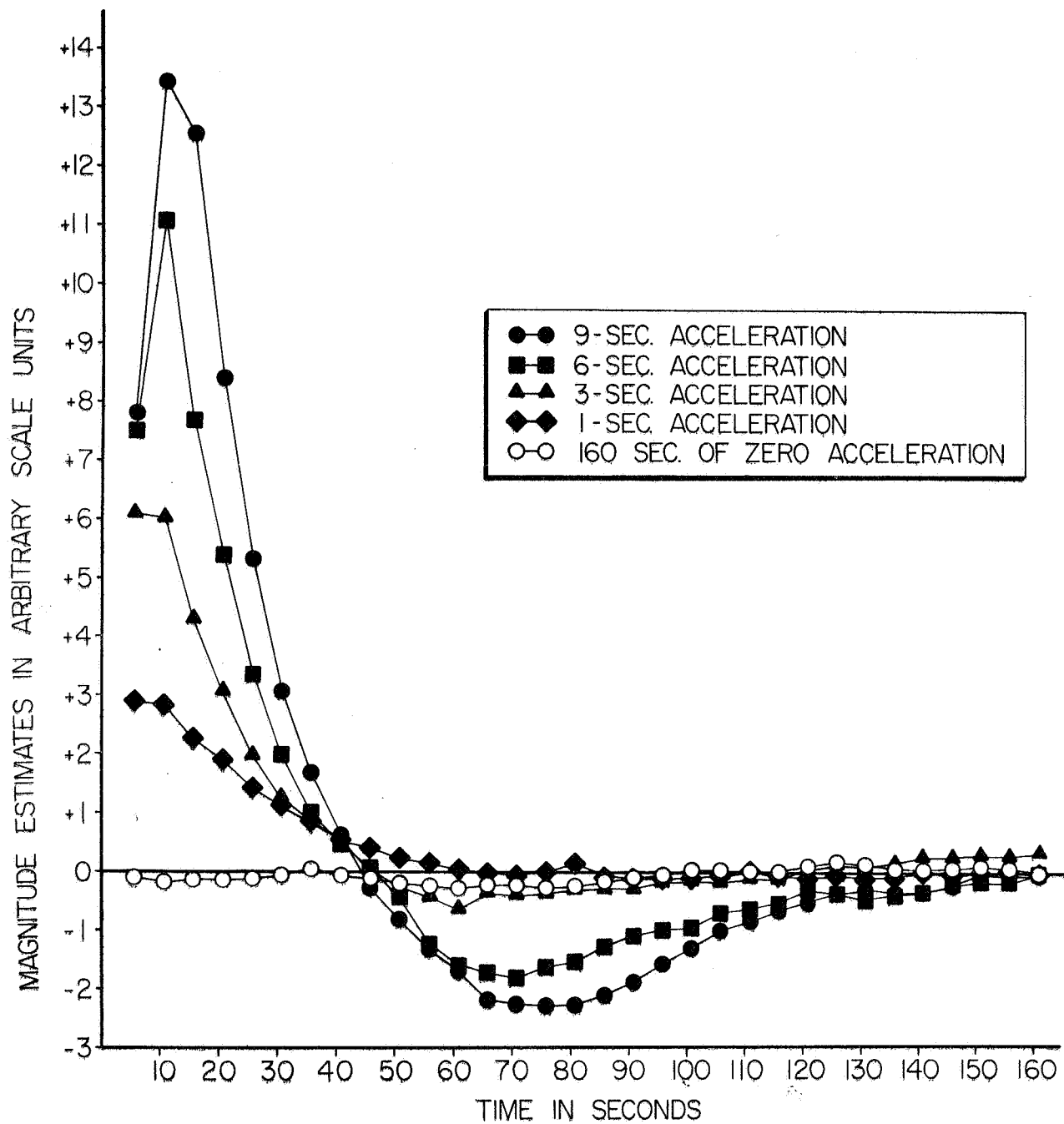


Figure 3. Magnitude estimates of the oculogyral illusion for 10 normal men for 9 sec. of angular acceleration (Parsons, 1968).

5. Thresholds for the perception of angular acceleration about the three major body axes. Clark, B., & Stewart, J.D. A paper to be presented at the Fourth Symposium on the Role of the Vestibular Organs in the Exploration of Space, U. S. Naval Aerospace Medical Institute, Pensacola, Florida, September 24-26, 1968.

Summary

Since very little data are available on the sensitivity to rotation about the various body axes, it was the objective of the present study to determine the thresholds for the perception of angular acceleration about the x-, y-, and z-axes of the body. The observers were 18 normal men who were rotated in the MCRD. Thresholds were determined using a forced-choice, random, double staircase method, and the order of threshold determination for the x-, y-, and z-axes was established by a Latin square procedure replicated three times. Mean thresholds and their standard deviations were essentially the same for the x- and z-axes. However, the mean threshold for the y-axis was higher and the individual differences were substantially greater than those for the x- and z-axes. It is suggested that these differences are due to psychological factors rather than to differences in function of the semicircular canals when placed in different positions with respect to gravity.

6. Effects of angular acceleration on man: Thresholds for the perception of rotation and the oculogyral illusion. Clark, B., & Stewart, J.D. (This study is being prepared to be submitted for publication).

This paper is concerned with the range of sensitivity of normal men to angular accelerations associated with passive body rotation which occurs in simulators, aircraft, and spacecraft. The specific purpose of the study was to measure man's sensitivity to angular acceleration using the perception of rotation and the perception of the oculogyral illusion as indicators. Thresholds for the perception of rotation about the observer's vertical axis have been obtained for 50 normal men and comparative data on both indicators have been obtained on 27. The data show clearly that the mean threshold for the perception of angular acceleration is of the order of $0.4^{\circ}/\text{sec}^2$, but there is a very large range of sensitivity from 0.05° to $2.24^{\circ}/\text{sec}^2$. Thresholds for the oculogyral illusion were found to be less than one third of those for the perception of rotation, and the variability for the oculogyral illusion was far below that of the perception of rotation. Furthermore the correlation between the thresholds for the two indicators was not significantly different from zero. This makes it clear from a practical point of view that one threshold, cannot be predicted from the other. It also suggests that separate sensory systems are involved in these two indicators of vestibular stimulation.

7. Autokinesis in a rotating simulator. Stewart, J.D.
(This report is in the preliminary stages of analysis).

The illusory motion of fixed, visual objects in darkness or visual autokinesis has been reported for hundreds of years. It has also been observed under loosely controlled conditions during flight. Similarly, apparent rotation of aircraft and aircraft simulators has been reported for years. We have called this gyroautokinesis. Although both phenomena are well known, neither has been studied under carefully controlled laboratory conditions in a rotating device. Data from control trials in an earlier experiment which produced gyroautokinesis and Parson's (1968) data above which reported visual autokinesis provide a controlled situation and are being analyzed in detail. Preliminary analysis suggests that there is a substantial amount of visual autokinesis and gyroautokinesis under these conditions. This study should elucidate the characteristics of these two illusory effects in simulators and aircraft and suggest possible complications in the use of motion information in the control of aircraft.