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Vestibular-Visual Interactions in Flight Simulators

PRINCIPAL INVESTIGATOR: BRANT CLARK

FINAL REPORT
NASA Grant No. NGL 05-046-002
SEPTEMBER 1977

San Jose State University
SAN JOSE STATE UNIVERSITY, SAN JOSE, CALIFORNIA 95192
DEPARTMENT OF PSYCHOLOGY
VESTIBULAR-VISUAL INTERACTIONS IN FLIGHT SIMULATORS

Final Report on NASA Grant No. NGL 05-046-002

September 1, 1967 to September 30, 1977

Project Director: Brant Clark

San Jose State University
Department of Psychology
San Jose, California 95192

1The NASA Technical Officer for his grant is John D. Stewart, NASA-Ames Research Center, Moffett Field, California 94035
This communication is the final report for NASA-Ames Research Center Grant No. NGL 05-046-002 to San Jose State University. It outlines the work undertaken from September 1, 1967 to September 30, 1977. From its inception, this project was conceived as a collaborative effort between faculty and students at San Jose State University and research scientists in the Life Sciences Research Laboratory at Ames Research Center. However, practically all of the experimental work was carried out at the Laboratory using the Ames Research Center's extensive computer and simulator facilities. This collaborative undertaking has served two major functions. In the first place it has supported a series of specific research projects proposed by the project director and a number of ongoing research projects being conducted in the Laboratory. Secondly, it has made a major contribution to the scientific development of a large number of San Jose State University students, primarily in the psychology department. Furthermore, the grant has resulted in a number of useful interactions between the faculty at the University and the research scientists in the Laboratory.

Research Projects

The research under this grant began as a series of psychophysical experiments concerned with vestibular function per se and specifically investigated man's sensitivity to rotary acceleration. This has resulted in thresholds obtained both in darkness and with a fixed visual reference on the largest group of men now available, and data are
available for both pilots and nonpilots. Data have also been collected on other psychophysical functions of the semicircular canals and such topics as the effects of rotary acceleration on tracking performance and monitoring type tasks. However, with succeeding years the objectives of the grant were broadened substantially to include vestibular-visual interactions in flight simulators and neurophysiological experiments dealing with the vestibular functions of animals. More recently the objectives of the grant have been broadened still further to include the study of the effects of other sensory systems in flight simulators and certain flight management investigations of concern in man-vehicle system interactions. Consequently, the tenth and final annual report summarized not only work on vestibular processes but also included studies of such diverse problems as: (1) the control of the signs and symptoms of motion sickness by biofeedback and autogenic training, (2) visual processes in simulated cockpit displays including Head-Up Displays, (3) auditory cue utilization in simulators, and (4) selected flight management problems including evaluation of work load and the use of synthetic speech callouts during the landing phase of simulated flight.

As a result of this broadening of the purposes of the grant, the experimental work conducted does not fall readily into a single, systematic investigation of a limited field. Moreover, the specific findings have been summarized in the 10 annual reports. Consequently, this report will simply bring together all of this work on man-vehicle interactions in a complete reference list of these contributions to aviation and space science. These reports have been arbitrarily
classified into three categories: (1) published papers, (2) papers read at professional meetings, and (3) completed masters theses at the University. It should be noted that the same experimental data are sometimes repeated in more than one of these categories. This reference list is to be found in Appendix A of this report.

Collaborative work between the University and Ames Research Center

The grant has also served as a vehicle for extensive interaction between the University and the Center. The extensive collaboration involved in the research effort can be shown in part by the number of University faculty members and the number of Ames research scientists who have taken part in the work which has culminated in the research reports listed in Appendix A. During the tenure of the grant, in addition to the project director, nine faculty members in the psychology department have been active on one or more thesis committees and several others have served in various advisory capacities in connection with the research work the student research assistants have carried out under the grant. These faculty members are listed in Appendix B.

Several research scientists at Ames Research Center have also contributed in a major way to the scientific training of the student research assistants through the students' work on the various research projects. The Ames research scientists who have worked most closely with the research assistants are listed in Appendix B, but many other members of the Ames staff have made important contributions to the work of the research assistants. Both the faculty and the students have also benefitted from contacts with visiting scientists at the Center, and
indeed, several of the students have had the opportunity to work for a period with some of the visiting workers.

The grant has made it possible for a large number of graduate and a few undergraduate students to profit by experience in the Laboratory. A total of 62 students have received support by the grant and 55 have worked as research assistants for extended periods (typically during an academic year) in the Life Sciences Research Laboratory. This work has made a major contribution to their scientific development and has served as a valuable supplement to their formal academic work on the campus. As evidence of this, 26 have completed masters theses based on work conducted in the Laboratory, and ten additional theses are in progress. Some 63 experimental reports have a student as the sole or as a joint author. Of the students who have worked on the grant, 23 have been accepted in graduate programs at other universities leading to a doctorate while 9 have already earned doctorates. Some additional details regarding the activities of these students are listed in Appendix C. Altogether the opportunity to have experience in a working research laboratory has been an invaluable contribution to the scientific training of these very able research assistants.
APPENDIX A

REFERENCES

Papers Published or Submitted for Publication


7. Clark, B., & Stewart, J. D. Comparison of three methods to determine thresholds for the perception of passive bodily


12. Clark, B., & Stewart, J. D. Comparison of the sensitivity to rotation of pilots and nonpilots. Aerospace Medicine, 1972, 43, 8-12.


15. Clark, B., & Stewart, J. D. Effects of angular acceleration on
man: Choice reaction time using visual and rotary motion information. Perceptual and Motor Skills, 1974, 38, 735-743.


21. Daunton, N. G., & Thomsen, D. D. Otolith-visual interactions in single units of cat vestibular nuclei. Neuroscience Abstracts,


28. Haines, R. F., Binocular summation of the peripheral retina to colored stimuli. Accepted for publication by the *American Journal of Optometry and Physiological Optics*.


33. Haines, R. F., Rositano, S. A., & Greenleaf, J. E. Visual field collapse and intraocular pressure changes associated with gradual onset of $+G_z$ acceleration. (Submitted for publication).

34. Halloran, T. O., Clark, B., & Stewart, J. D. Reaction time to accelerating lines and dots on a cathode-ray tube. (Submitted for publication).


43. Shvartz, E., Haines, R. F., Bhattacharya, A., Hodges, R., Dawson, L. M., & Greenleaf, J. E. Tilt table and exercise responses to two conditions of water-immersion, chair-rest, and bed-rest procedures. (Submitted for publication).

45. Simpson, C. A., & Hart, S. G. Required attention for synthesized speech perception for two levels of linguistic redundancy. 

46. Stewart, J. D., & Clark, B. Choice reaction time to visual motion during prolonged rotary motion in airline pilots. 
*Aviation, Space, and Environmental Medicine*, 1975, 46, 767-771.

47. Stewart, J. D., & Clark, B. Factors affecting motion sickness in space: Sensory rearrangement or reduced vestibular function. 

48. Zahn, J. R., & Haines, R. F. The influence of central search task luminance upon peripheral visual detection time. 
Papers Read at Professional Meetings


51. Clark, B. The psychology of man in motion. Paper read at the San Jose State University Proseminar for Faculty, San Jose, California, December 11, 1973.

52. Clark, B., & Stewart, J. D. Thresholds for the perception of angular acceleration in a precision rotation device. Paper read at the meeting of the Aerospace Medical Association, Miami Beach, Florida, May 6-9, 1968.


55. Clark, B., & Stewart, J. D. Change in adaptation level during prolonged constant angular acceleration. Paper read at the meeting of the Aerospace Medical Association, St. Louis, Missouri, April 27-30, 1970.


57. Clark, B., & Stewart, J. D. The power law for the perception of rotation by airline pilots. Paper read at the meeting of the Western Psychological Association, San Francisco, April 1971.


60. Clark, B., & Stewart, J. D. Pilots' reaction time to motion on a visual display increases with increasing rotary acceleration. Paper read at the meeting of the Aerospace Medical Association, Washington, D.C., May 1974.

62. Countiss, R. B. Adaptation effects on magnitude estimates and frequency tracking during prolonged sinusoidal angular accelerations. A paper read at the Spartan Psychological Association Meeting, Department of Psychology, San Jose State University, April 1975.


University, Rome, September 1975.


70. Dockstader, S. L. Comparison of cupulometric and psychophysically derived angular acceleration thresholds for the oculogyral illusion and the perception of rotation. Paper read at the Rocky Mountain Psychological Association Meeting, Albuquerque, New Mexico, May 1969. Also read at a Psychology meeting at San Jose State University, April 1969.

71. Elsner, W. The power laws for the perception of rotation and the oculogyral illusion—a comparison. Paper read at the Spartan Psychological Association Meeting, San Jose State University, April 1969.


75. Halloran, T. O., Clark, B., & Stewart, J. D. Influence of stimulus size and configuration on pilots' reaction time to accelerating cathode-ray tube displays. Paper presented at the meeting of the Western Psychological Association, Los Angeles, April 1976.


77. Hamerman, J. A. Choice reaction time to movement of eccentric visual targets during concurrent rotary acceleration. Paper read at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, May 5-6, 1977.


79. Hart, S. G. The workload assessment program being developed at Ames


85. Hart, S. G., & McPherson, D. Airline pilot time estimation during


93. McCarty, M. A proposed methodology for the study of linearvection in pigeons. Paper presented at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, April 1976.


95. Mattson, D. L. The effect of stimulus length and orientation on the perception of an accelerating visual stimulus. Paper read at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, May 9, 1974.


100. Pardo, B. G. Effects of verbal communication and task variables on different air traffic control configurations. Paper read at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, April 1975.


102. Reid, L. M. Detection of peripheral warning signals during simulated night aircraft flight. Paper read at the Spartan Psychological Association Meeting, San Jose State University, San Jose, California, April 1975.

104. Shvartz, E., Bhattacharya, A., Sperinde, S. J., Brock, P. J.,
    Sciaraffa, D., Haines, R. F., & Greenleaf, J. E. Heat accli-
mation and water-immersion deconditioning: responses to exercise. A paper presented at the Aerospace Medical Association
    Meeting, May 9-12, 1977, Las Vegas, Nevada.

105. Silverstein, C. I. Temporal order judgments and response latencies
to rotary and visual accelerations in airline pilots. A paper
    read at the Spartan Psychological Association Meeting, San
    Jose State University, San Jose, California, May 10, 1974.

106. Silverstein, C. I. Temporal processing of rotary and visual acceler-
erations: Temporal order judgments, simple and choice reaction
time. A paper read at the meeting of the Western Psychological
    Association, Sacramento, California, April 1975.

107. Simpson, C. A., & Williams, D. H. Pilot preferences for the design
    of future cockpit warning systems. Invited paper presented
    at the meeting of the International Air Transport Association,

108. Simpson, C. A., & Williams, D. H. Increased response time associa-
ted with an alerting tone before synthesized voice warnings
during a simulated approach and landing study. Invited paper
    presented at the meeting of the International Air Transport

109. Stewart, J. D., & Clark, B. Correlation between five measures of
    vestibular function in airline pilots. A paper read at the
    meeting of the Aerospace Medical Association, Miami Beach,

111. Thomsen, D. D. Habituation to precise coriolis stimulation in the rat. Paper read at the meeting of the Western Psychological Association, Anaheim, California, April 1973.


Theses Completed

114. Beck, L. J. **Determination of the minimal disturbance level at which spurious angular accelerations affect compensatory tracking.** M.A. thesis, San Jose State University, San Jose, California, August 1972.


116. Chastain, P. R. **Thresholds for the oculogyral illusion during sinusoidal rotary acceleration.** M.A. thesis, San Jose State University, San Jose, California, August 1976.

117. Countiss, R. B. **Adaptation effects on magnitude estimates and frequency tracking during prolonged sinusoidal angular accelerations.** M.A. thesis, San Jose State University, San Jose, California, August 1975.

118. Cronn, F. W. **Comparison of two-head up display systems in simulated aircraft landing approaches.** M.A. thesis, San Jose State University, San Jose, California, August 1973.

119. Dockstader, S. L. **Comparison of cupulometric and psychophysically derived angular acceleration thresholds for the oculogyral illusion and perception of rotation.** M.A. thesis, San Jose State University, San Jose California, June 1969.

120. Doty, R. L. **The effect of the duration of stimulus presentation upon the angular acceleration threshold in man.** M.A. thesis, San Jose State University, San Jose, California, June 1968.
121. Elsner, W. The power laws for the perception of rotation and the oculogyral illusion—a comparison. M.A. thesis, San Jose State University, San Jose, California, August 1969.


127. Looper, M. Inhibition of choice reaction time to visual motion by concurrent rotary motion and selected loading tasks. M.A. thesis, San Jose State University, San Jose, California, August 1974.


131. Pardo, B. G.  *Effects of verbal communication and task variables on different air traffic control configurations.* M.S. thesis, San Jose State University, San Jose, California, August 1975.

132. Parsons, R. D.  *Magnitude estimates of the oculogyral illusion during and following angular acceleration.* M.A. thesis, San Jose State University, San Jose, California, August 1968.

133. Petitt, J.  *Perceived size under two viewing conditions compared with direct viewing of an outdoor scene.* M.A. thesis, San Jose State University, San Jose, California, July 1976.

134. Reid, L. M.  *Response time to red, yellow, green, and white peripheral signals during simulated night aircraft operations.* M.A. thesis, San Jose State University, San Jose, California, January 1976.

135. Roberts, D. C.  *The effects of attention, knowledge of results, and paired associations upon the levels of sensitivity of the semicircular canals.* M.A. thesis, San Jose State University, San Jose, California, June 1972.


APPENDIX B

San Jose State University Faculty Members who have advised Research Assistants.

Research Scientists at Ames Research Center with whom the Research Assistants have worked.

Clark, Brant
Fox, Robert
Ginsberg, Rose
Goodwin, Dwight
Hicks, Robert
Minium, Edward
Rabedeau, Ronald
Richardson, Harold
Sawrey, James
Witte, Robert
Baty, Daniel
Coler, Clayton
Daunton, Nancy
Haines, Richard
Huff, Edward
Nagel, David
Palmer, Everett
Stewart, John
Tanner, Trieve
Wempe, Thomas
# APPENDIX C

**ACTIVITIES OF STUDENTS WHO HAVE WORKED ON THE GRANT**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Total number of students who have been supported by the grant.</td>
<td>62</td>
</tr>
<tr>
<td>2. Number of research assistants.</td>
<td>55</td>
</tr>
<tr>
<td>3. Number of completed masters theses based on work in the Laboratory.</td>
<td>26</td>
</tr>
<tr>
<td>4. Number of theses in progress in the Laboratory.</td>
<td>10</td>
</tr>
<tr>
<td>5. Number of experimental reports with a student as the sole author.</td>
<td>28</td>
</tr>
<tr>
<td>6. Number of experimental reports with a student as a joint author.</td>
<td>35</td>
</tr>
<tr>
<td>7. Number of these students accepted in Ph.D programs.</td>
<td>21</td>
</tr>
<tr>
<td>8. Number of Ph.Ds completed.</td>
<td>8</td>
</tr>
<tr>
<td>9. Number of M.D. degrees completed.</td>
<td>1</td>
</tr>
<tr>
<td>10. Number of students in a DVM program.</td>
<td>1</td>
</tr>
<tr>
<td>11. Number of former students known to be working as professional psychologists</td>
<td>17</td>
</tr>
</tbody>
</table>