The First Four Minutes: Human Factors in Suborbital Spaceflight

Janna Kaplan[1,2], Paul DiZio[1], James R Lackner[1], Alberto Pierobon[1], Lila Fakharzadeh[1], Joel Ventura[1,2], Marco Giovanardi[3], Aditya C Chetty[3], Saul M Silverberg[3], Zack M Anderson[3], Jack A Ekchian[3], Mario Flores[3]

[1]Ashton Graybiel Spatial Orientation Lab, Brandeis University, Waltham MA 02453
[2]Sirius Astronaut Training, 415 South Street, MS033, Waltham MA 02453
[3]ClearMotion, Inc. 805 Middlesex Turnpike, Billerica, MA 01821

Abstract

The commercial spaceflight industry is nearing a flight-ready status with human occupants onboard. Over the preceding years, the industry downplayed possible human factors disturbances by suggesting that a suborbital parabola is too brief to produce adverse effects. Our observations made in NASA's parabolic flight, in the Graybiel Lab's Rotating Room / Artificial Gravity analog environment, and our research done in collaboration with ClearMotion, Inc., a company designing advanced vehicle suspension systems for conventional and autonomous vehicles, prove otherwise.

Occupants' Sensory-Motor Disturbances in Initial Minutes of Road Ride and Ride in Autonomous Vehicle Simulator

Data of motion sickness and subjective sense of comfort, as well as ability to read and comprehend a text, were collected from passengers driven for 30 minutes on a moderately "bumpy" road. Comparisons were then made with similarly collected data from the same subjects tested as occupants in a vehicle simulator, where the pre-recorded acceleration profile of a vehicle with a conventional suspension driven over a real road, above, was played back in a parked vehicle where it could either emulate a conventional passive suspension system or actively cancel road vibration by using a playback mode with various degrees of fidelity. In one condition, the road acceleration was unmitigated and reproduced as faithfully as possible (unattenuated test case) and in the other, acceleration was attenuated with a broadband filter on the suspension system that had been tuned for ride comfort.

In all conditions, baseline data were first collected with no vehicle or simulator motion and then during 30 minutes of real or simulated motion, in 5- minute epochs. We recorded the following subject self-reported and experimenter observed parameters, on 0 to 10 scales: 1) level of nausea; 2) drowsiness; 3) eye strain; 4) difficulty comprehending the text; and 5) subjective ride comfort. At the end of each testing epoch, the experimenter guided the subject through the questions of the Graybiel diagnostic criteria for acute motion sickness.

Comparison with Initial Parabolas in Parabolic Flight and in Artificial Gravity Analog Environment

Although there is large individual data variability, the aggregated results showed that, in the unmitigated test case, motion sickness symptoms developed within the first two motion/simulation epochs which span the first 2-5 minutes of stimulation. Motion sickness increased in the simple subjective nausea measurements as well as when assessed by a more comprehensive Graybiel Scale. Subjective rating of overall comfort decreased, and eye strain and difficulty in reading increased. A similar timeline of human factors disturbances was observed in parabolic flight where individuals may get severe motion sickness within the first two parabolas, and in the rotating / artificial gravity environment where even small, involuntary head movements may elicit motion sickness and disorientation.

Conclusions

Human factors are thus likely to play an adverse role in suborbital flight. However, in our emulated test cases, all negative effects decreased when attenuation was applied to vehicle suspension, which proves that countermeasures are possible. Similarly, pre-flight adaptive training may limit or prevent in-flight discomfort and sensory-motor disturbances.