The Perceptual Effects of Altered Gravity on Tactile Displays

Final Report and Outreach Activities

NASA Reduced Gravity Student Flight Opportunities Program

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Purdue University College of Electrical and Computer Engineering
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Abstract

Spatial disorientation (SD), a false perception of one's attitude or orientation, is a major problem facing pilots and NASA astronauts alike. Spatial disorientation mishaps cost the Department of Defense $300 million annually in lost aircraft, dozens of lives and can give astronauts debilitating motion sickness. This project was a continuation of previous experiments investigating haptic (touch) perception in altered-gravity environments. Data collected during two previous flights under the NASA Reduced Gravity Student Flight Opportunities Program showed that (1) haptic performance deteriorated in zero-gravity environment; and (2) this deterioration was not due to a change in hardware performance, or a change in perceived intensity of haptic signals in zero-g. The current project investigated the role of cognitive load in affecting haptic performance in a zero-g environment. In microgravity, test subjects felt a buzz in one of ten possible torso tactors and recorded on a keypad which tactor they felt. Two test subjects performed this each parabola, one strapped to the floor of the airplane and the other free floating. We hypothesized that the signal-recognition rate for the subject who will be strapped to the floor of the KC-135 will be higher than the subject who will be free-floating in zero-g. Performance was assessed through comparing accuracy in identifying a haptic stimulus on the torso by the flying and the immobilized member, and by comparing information transmission through the multi-tactor vests worn by these two flight members. According to the data collected in microgravity, an increase in cognitive load adversely affects one's ability to distinguish vibrotactile stimulations.

Results

Subject response data from both preflight testing and the microgravity portion of the testing was downloaded from the microcontroller into a text file. For each subject, the recorded responses were compared to the actual stimuli. The number of trials and percent correct were calculated for preflight conditions of standing up and lying down. High cognitive load (free floating) and low cognitive load (strapped down) microgravity conditions were compared and the percent of correct responses were determined for each subject. With regard to statistical analysis, population one was strapped down and population two was free-floating subjects. A two sampled proportion test was then performed on the percent correct of the two populations for all four test subjects. Over 350 trials were obtained and the sampling distribution of the data follows a normal distribution.

The experimental preflight results are shown in Table 1. Preflight tests took place in one-g conditions, and identical results were expected. As hypothesized, the percent correct of the group standing up versus lying down are nearly identical, being 88.5% and 90% respectively, showing only a difference of one and a half percent.

Table 1. Pre-Flight Ground Data

	Lying Down		Standing Up	
Subject	No. of Trials	% Correct	No. of Trials	% Correct
Anu	418	79.7	400	75.3
Jonathan	158	93.0	183	85.2
Kim	383	97.4	392	96.7
Mike	400	92.5	409	95.1
Group	1359	90	1384	88.5

Table 2 is data from the microgravity flight for all four test subjects. There is a large difference in the percentage correct between strapped down (low cognitive load) and free floating (high cognitive load). The percent correct for the low cognitive load condition is 82.9% while the percent correct for the high cognitive load condition is 47.4%. The zero-g, low cognitive load situation is 35.5 percentage points higher. Set the null hypothesis that the average percent correct for both conditions is equal and the alternative hypothesis that the percent correct for both conditions is not equal. Statistical analysis yields a p-value of zero, rejecting the null hypothesis (of equal percent correct.)

Table 2. Flight Data

	Strapped Down		Free-floating	
Subject	No. of Trials	% Correct	No. of Trials	% Correct
Anu	196	74.5	160	40.6
Jonathan	90	73.3	29	34.5
Kim	151	90.1	78	47.44
Mike	172	91.3	92	63.04
Group	609	82.9	359	47.4

One concern was the effect of anti-nausea medication in microgravity tests. For subjects Jonathan and Kim, on ground post flight testing was performed within 5 hours of taking the medication. The testing and procedure was the same as that done during preflight and flight experimentation. Similar results came from these tests to those obtained in preflight testing. The percent correct for standing up versus lying down is 93.4% and 90.7% respectively, with a difference of 2.7 percentage points.

Table 3. Post-Flight Ground Data with Medication

	Lying Down		Standing Up	
Subject	No. of Trials	% Correct	No. of Trials	% Correct
Jonathan	182	84.1	211	88.6
Kim	214	96.3	211	98.1
Group	396	90.7	422	93.4

Discussion

The subjects found it very difficult to concentrate in zero gravity free floating. Due to the extremely unusual nature of this environment, much of one's attention is focused on avoiding collisions or absorbing the awe of floating.

Three of the four subjects were first time microgravity test subjects. It is significant to note that the experienced flyer (Mike) had the highest percent correct in both zero-g conditions (See Table 2, Flight Data). It is unclear if he had higher concentration or motivation, yet one can observe he did not have the highest scores in the pre-flight ground data.

Conclusion

According to the data collected aboard the KC-135A, an increase in cognitive load adversely affects one's ability to distinguish vibrotactile stimulations in a microgravity environment. This confirmed our hypothesis. Medication did not appear to adversely affect one's ability to correctly identify stimuli; however further rigorous research needs to be done for a conclusive answer.

Outreach Activities

High School

On October 3, 2003, the team gave a presentation to a physics class of approximately 25 students at Jefferson High School in Lafayette, IN. The presentation discussed the Reduced Gravity Student Flight Opportunities Program, effects of microgravity, and the experiment of haptic interfaces and cognitive load. This class created a small experiment to test in microgravity. The experiment observed the behavior of different types of materials in clear tubes under zero gravity. It was flown and videotaped for several parabolas. We will give a follow up presentation to show the class the video footage of their experiment, our experiment, and discuss how they can get involved.

General Public

On October 4, 2003, the team had a booth in an engineering fair that was a part of the Purdue Homecoming festivities. Current students, alumni, others affiliated with Purdue University, and the general public attended this event. We showed a video from a previous group's flight and talked to the attendees about the RGSFOP in general, past research from previous flight groups from the Electrical and Computer Engineering department, and the experiment we would be performing.

Website

We actively maintain and promote our website, www.IFlyVomitComet.com through our community outreach, school visits and on our resumes. On this website, visitors can learn about our program, see pictures and video, and sign up for a free newsletter.

Press coverage

A reporter from the L.A. Times, Scott Gold, joined our team in Houston. His article is still pending. Two articles were published in Jonathan's hometown, Fort Wayne, IN.

Elementary School

The team will give a presentation for 5th and 6th grade students at Happy Hollow Elementary School. The upcoming presentation will be about 30 minutes long discussing space in general, and what it is like to be weightlessness. The video footage of the experiment will be played to explain them what we have felt in weightlessness and how our experiment was conducted. At the end of the presentation, we will have a few randomly selected students put on our vests to better understand our experiment and add a "hands on" dimension to the visit.