Improving Human Task Performance with Luminance Images and Dynamic Overlays

James C. Maida, Johnson Space Center
Charles K. Bowen, Lockheed Martin
John W. Pace, Lockheed Martin
Maria R. Ortiz, SPACEHAB
Michele H. Segal, SPACEHAB

The goal of this project was to investigate and measure the effects on crew performance of the Space Station tasks of computer-aided training, enhanced with static lighting, dynamic lighting, and dynamic overlays.

Previous research ("Human Task Performance Evaluation with Luminance Images" – NRA 95-OLMSA-01) has shown the use of static lighting in computer-aided training simulations improved performance by humans when humans executed the tasks for which they were trained. The project extended this line of research to include dynamic lighting effects, which are common with a 45-minute orbital day. In addition, the project also examined the use of augmented reality techniques, such as dynamic overlays, to enhance training and task execution during poorly or ambiguously illuminated situations.

Twenty-four male and 24 female participants were trained with a computer simulation of an alignment task using a Space Station docking target pattern. During training with normal simulation and training with simulation augmented with overlay information, three conditions were considered: no lighting (traditional computer modeling), static lighting, and dynamic lighting conditions. After the training, each participant was tested with two viewing conditions: normal video and video augmented with overlay information.

Results from the project showed that, under some conditions, error was reduced with the use of overlays. Consistent gender effects were noted in both training and testing performance. Use of overlays resulted in increased confidence in participants. Though not statistically significant, subjects trained with static and dynamic lighting conditions showed a tendency toward improved accuracy.

The lighting conditions under which astronauts conduct on-orbit tasks are very different from the lighting conditions encountered conducting ground-based tasks. The Sun rises and sets every 45 minutes on average, creating dynamic lighting conditions depending on orbital attitude. In the case of the current Space Station attitude, the Sun appears to move at a rate of about five degrees per minute, causing shadows to move across the field of view. Because of the lack of atmospheric diffusion, shadows in space can produce high-contrast situations for both direct and indirect viewing. In addition, the operation may need to be performed in both daylight and darkness, making operation of a camera with a wide range of light sensitivity an important part of the training.

Currently, crews are exposed to an approximate representation of these conditions during training using mockups of camera targets and large luminaries to produce Sun-like conditions with shadowing. The disadvantage of this type of training is that mockups are inflexible and expensive when mission scenarios change. The preferred method for training is the use of a computer-based, real-time simulation where its flexibility is part of its cost effectiveness. However, real-time, physically based simulators have limitations when lighting conditions are not ideal. These computer simulations typically do not have static or dynamic shadowing, glare, or accurate low-light conditions because the computational cost is too high or because the technology has not been developed sufficiently. A key question addressed by this project is "How much does real-time

shadowing and dynamic overlays (augmented reality) improve training in a simulation?" The degree of improvement will determine whether the cost of adding this feature to a real-time simulation is justified.

It is the project hypothesis that on-orbit human task performance will be enhanced by including accurately illuminated, dynamic computer-generated camera images and augmented video in training procedures that prepare the crew for on-orbit operations.

Forty-eight subjects were used. The group was gendered balanced. The 24 females were between 20 and 30 years of age. The males were between 20 and 50 years of age, with 19 males being between 20 and 30 years of age. All participants possessed vision correctable to 20/20 and were in general good health.

There were two phases: training for a task and executing the task. The training phase was broken into two groups: with overlays and without overlays. Within each group, everyone was trained with no lighting, static lighting, and dynamic lighting. All subjects were tested with and without video overlays.

Mean docking error was lower for participants who trained with overlays ($P < 0.001$). Time to completion increased on average for females ($P < 0.0005$), decreased with successive trials ($P < 0.0005$), increased with more realistic lighting. ($P < 0.001$), and increased with the use of overlays ($P < 0.004$).

Subjects were divided into two groups (A and A') based on the path of the light during the test. For Group A, mean docking error was lower for participants during testing with overlays ($P < 0.0005$); for Group A', no significance was detected. Time to completion for Groups A and A' increased on average for females. $P < 0.006$, $P< 0.0005$ and for Group A' for those with dynamic lighting training ($P < 0.002$).

Under some conditions, training with overlays reduced errors. Consistent gender effects were noted in both training and testing performance. Use of overlays resulted in increased confidence in participants. Under dynamic lighting conditions during testing, performance was adversely affected. We found no statistical significance that training with shadows improved performance during testing. However, when the accuracy demand (i.e., the distance from the end point of the user's selected stopping point to the exact position) was increased and applied as a pass/fail test, there was a trend in favor of training with static and dynamic shadowing conditions. Additional testing may find more significant impacts on task performance when subjects are trained with appropriate lighting conditions.