Wednesday, June 11

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Session WP2
Room 2
2:30 - 5:30 p.m.

Human Factors Research Under Ground-Based and Space Conditions - 2

TRAINING ASTRONAUTS USING THREE-DIMENSIONAL VISUALIZATIONS OF THE INTERNATIONAL SPACE STATION

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Recent advances in Personal Computer technology have led to the development of relatively low-cost software to generate high resolution three-dimensional images. The capability both to rotate and zoom in on these images superposed on appropriate background images enables high-quality movies to be created. These developments have been used to produce realistic simulations of the International Space Station on CD-ROM. This product will be described and its potentialities demonstrated. With successive launches, the ISS is gradually built up, and visualized over a rotating Earth against the star background. It is anticipated that this product's capability will be useful when training astronauts to carry out EVAs around the ISS. Simulations inside the ISS are also very realistic. These should prove invaluable when familiarizing the ISS crew with their future workplace and home. Operating procedures can be taught and perfected. "What if" scenario models can be explored and this facility should be useful when training the crew to deal with emergency situations which might arise. This CD-ROM product will also be used to make the general public more aware of, and hence enthusiastic about, the International Space Station program.

MEASUREMENT AND VALIDATION OF BIDIRECTIONAL REFLECTANCE OF SHUTTLE AND SPACE STATION MATERIALS FOR COMPUTERIZED LIGHTING MODELS

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INTRODUCTION

Awareness of surroundings critically impacts an astronaut's ability to carry out assigned tasks. Evaluation of lighting conditions for performance of on-orbit tasks and training with realistic lighting are important to successful shuttle missions and for the assembly of Space Station. Since the Gemini program, NASA's Johnson Space Center has used ground-based mockup testing and scale models to evaluate on-orbit illumination and to provide training for astronauts. Some of these procedures are very expensive to carry out and only partially simulate the actual conditions. In order to evaluate lighting conditions which cannot easily be simulated on Earth, the Graphics Research and Analysis Facility (GRAF) has been developing the capability to provide computerized simulations of various illumination conditions using the ray tracing program, Radiance, developed by Greg Ward at Lawrence Berkeley Laboratory. This capability permits the computational prediction of light levels on surfaces in complex configurations for visibility or viewing analysis. The sun, diffuse earth shine, and/or a collection of vehicle-based lights may be used as lumination sources. Computed lighting levels (luminance from surfaces and illumination on surfaces) were validated by comparing computed values to measurements made during ground-based lighting tests.

MATERIAL REFLECTANCES

Successful use of the GRAF lighting modeling depends on having material properties that describe the reflection of light from various spacecraft structures (overall reflectivity of the surface, the distribution of the reflected light in each direction from the material surface, and the distribution of the incident light being reflected.) The reflectivity of a material is the ratio of the reflected light intensity to the incident light intensity at any angle in a hemisphere above the plane of the reflecting surface (Bidirectional Reflectance, BR). BR depends on the material reflectance and the angle of the reflected light. The Bidirectional Reflectance Distribution Function (BRDF), the ratio of the reflected luminance to its incident illumination, is constant at all angles for a perfectly diffuse material, but will have a peak at the angle of incidence equal to the angle of reflection when the material also has a specular component. The measured reflectance data can be described with three parameters: the total reflectance, the amount of this reflection which is specular, and the angular width of the specular distribution.

BR and BRDF can be measured with a gonioreflectometer, which collects reflected values from a material sample over the angles in a hemisphere. The constant diffuse component was determined by averaging values from a hemispherical sweep in 5 degree steps. A high resolution sweep in 0.5 degree increments was then run around the approximate peak of reflectance to determine the peak value, peak location, and width of the specular reflectance.

The averaged diffuse reflectance component was important because this constant was integrated over the hemisphere when calculating the total reflectance and was also subtracted from the specular peak during the process of fitting a Gaussian curve to the data. A computer program was written to process the hemispherical sweep data and produce the constant diffuse reflectance component by averaging points in the data set.

Once the diffuse reflectance component was determined, the fine angular sweep was used to determine the width and height of the specular component by plotting the intensity for each point against the angle between the peak angle and the vector, yielding a 2D plot. The best Gaussian fit to the data was found, after subtracting the constant diffuse value. This "best fit" Gaussian peak amplitude and width, along with the constant diffuse component were used to generate the actual parameters needed for Radiance. The half width at half maximum(HWHM) is calculated by finding the angle in the Gaussian fit where the BRDF value is half the value at the Gaussian peak.

VALIDATION OF COMPUTER LUMINANCE CALCULATION

When accurate lamp and material properties, along with accurate geometric objects, are incorporated into the Radiance lighting calculation, the computer calculation of the luminance from each surface in the scene should agree with measured luminance values within the limits of accuracy of the model and the measurements. Limitations of comparisons between calculated and measured values are: light sources may not have uniformly regular distributions, lamp intensities degrade over time, material surfaces may be non-uniform, and slight errors in orientation of lamps or surfaces can result in significant differences in measured luminance values.

Three earth-based tests have been used to check the luminance calculations against measured values. These three tests provided validation of the modeling under different lighting conditions. The first test used the solar simulator to model the effects of direct sun light on the docking target used in the Shuttle-MIR docking. The second test used shuttle Remote Manipulator Assembly (RMA) lights on the docking module to simulate exterior shuttle lights for night time Shuttle-MIR docking. The third test used interior station fluorescent lighting in a mockup of the International Space Station Habitation Module where multiple reflections from surfaces are important.

RESULTS

The reflected distribution of light from more than 70 samples including 42 interior and exterior Shuttle and ISS paints, Shuttle Tiles and Thermal Blankets used to protect the Shuttle during re-entry, materials for the Hubble Space Telescope, materials used for ISS structures and thermal protection, and material from the Russian MIR Space Station were collected. A process was developed to convert this data into Radiance Parameters forming a data base which includes the total reflectance from the surface, the percent of the total reflectance that is specular, and the angular width of the specular distribution for each material. It was found that the measured specular widths of the paint samples could be grouped according to the type of finish: gloss, semi-gloss, or flat. A statistical analysis of these samples found a mean HWHM of 1.64 $\pm$0.20 degrees for all gloss samples, and 5.464 $\pm$2.06 degrees for semi-gloss samples. All flat samples were treated as being entirely diffuse. From the results of the gloss samples, it is clear that as long as the paint is thick enough to completely cover the surface to prevent reflections from the material surface on which the paint is applied, then the under surface can be ignored.

A data base of light values was also compiled for most of the luminaries in the Shuttle and Space Station programs which included part number, location/use, size, power, peak illumination, and beam width.

CONCLUSION

Methods of predicting luminance levels have been shown to be reasonably accurate for a variety of lighting conditions including direct sun light and artificial lighting. The Radiance calculations have shown good results for both exterior and interior lighting environments.

These luminance calculated images are being displayed using algorithms which model Shuttle camera parameters to produce accurate simulations of the Shuttle and ISS cameras in order to determine light levels that are adequate for camera viewing. The figure below shows an actual downlink video image from STS-80(left) and a computed image generated 2 months before launch.

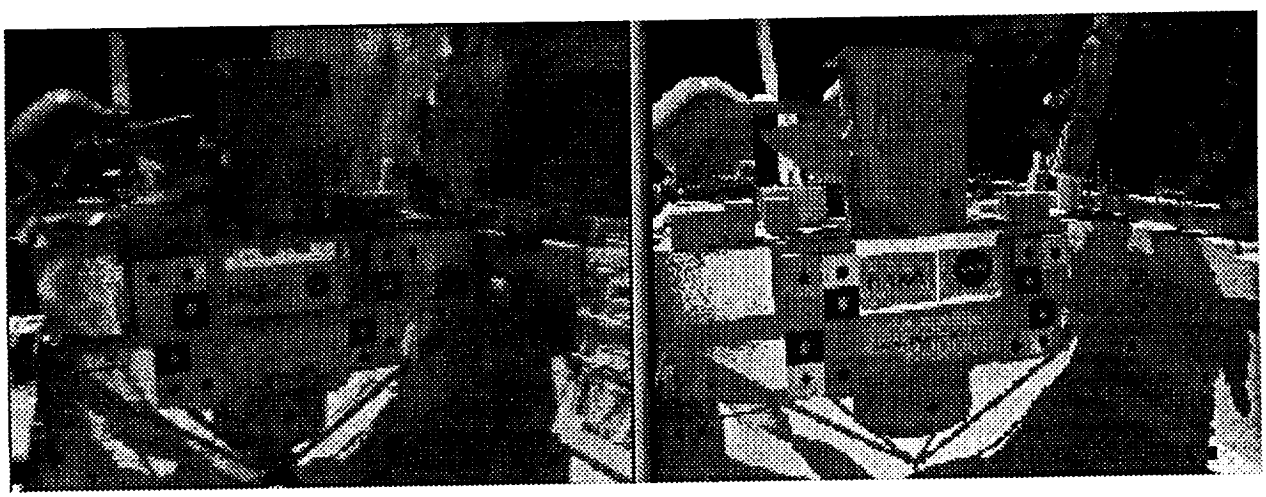

Figure: Image on left is downlink video from STS-80. The image of the right is computer generated, two months before launch. Slight differences in beta angle, geometry, and time do not have a major impact on the basic luminance image.

EFFECTS OF ENVIRONMENTAL COLOR ON MOOD AND PERFORMANCE OF ASTRONAUTS IN ISS

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INTRODUCTION

Effects of the interior environment on astronauts' feelings of well-being, morale, and productivity are important—especially when considering upcoming long-term space flights on the International Space Station (ISS). Varied social-cultural backgrounds of crew members may affect their mood and performance while living/working together in the confined space of the habitation module. On earth or in space, interior color can have a great environmental effect on individuals. However, individuals differ in their ability to screen out environmental stimuli. Individual sensitivity within a particular environment might hinder performance. On the other hand, some individuals, having a higher threshold level, might need more environmental stimuli to perform at optimum level.

METHODS

The purpose of this study was to examine the impact of three color schemes in confined spaces on mood, worker productivity, and performance over a 4-day work week relative to individual differences in environmental sensitivity. Matched on relevant variables, 90 subjects were randomly assigned to one of three confined spaces. Each confined space was painted either predominantly bright red, light blue-green, or the white color used by NASA for the habitation module mock-up at JSC. The bright red and light blue-green color schemes were derived from the conclusions of a NASA sponsored literature review on the effects of interior color on individual characteristics such as mood, performance, and productivity. Data on a series of experiments were collected. The first involved data on individual mood characteristics which were collected twice daily. Short-term productivity tasks based on 30 minutes of standardized clerical tasks were administered on the first and the fourth work day. A major phase examined the impact of color on longer-term office tasks such as proofreading and typing administered at intervals for 1 hour and 15 minutes each workday.

RESULTS

For mood, on average, higher scores for Confusion and Tension were reported by workers in the red space than in the blue-green, while higher scores for Vigor were reported in the blue-green than in the red. Low screeners scored higher on Depression in the white space than high screeners. In terms of performance, primarily on the third and fourth days, subjects made more errors on proofreading and typing in the blue-green color, and to a lesser degree in the red space than in the white space. This was true regardless of stimulus screening ability. On the first and second work days, workers with high screening ability in the predominantly red color performing the long-term proofreading and typing tasks were more productive than workers with low screening ability. Conversely, on the first and second work days, workers with low screening ability were more productive on the long-term proofreading and typing tasks than high screeners in the light blue-green space. This was similar to the findings on short-term clerical tasks.

CONCLUSION

In examining the effects of the three different schemes on productivity and performance, the results suggest that individual stimulus screening ability may act as a moderating variable influencing how individuals experience a particular interior color. Implications about mood, performance, and productivity of astronauts during long-term space flight on ISS' habitation module will be discussed.

The study was developed under a grant sponsored by the Institute of Business Designers Foundation (IBDF) and funded by BASF Corporation and Interface Flooring Systems, Inc.

PSYCHOPHYSICAL MEASURES OF MOTION AND ORIENTATION: IMPLICATIONS FOR HUMAN INTERFACE DESIGN

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INTRODUCTION

Numerous methods have been used to elicit precise information from a subject regarding the orientation and motion he experiences in a dynamic motion environment. Finding the best method for a given situation is crucial to understanding problems such as spatial disorientation and for designing human-machine interfaces. NAMRL has embarked on a multi-year research effort, dedicated in part to evaluating various psychophysical measures of spatial orientation.

METHODS

In our first study, each upright subject (S) received a range of linear x-axis oscillations on a linear track, with resultant y-axis force angles of 15° and 30°. As a control, Ss were exposed to angular oscillation using the same frequencies and true y-axis pitch angles. We explored a variety of static and dynamic approaches to collecting body orientation estimates, including retrospective and concurrent verbal reporting of tilt and retrospective and concurrent laser horizon tracking. In our second study, Ss were exposed to head-centered y-axis rotation which progressed from 6 to 30 rpm in incremental steps and their responses were elicited every 30 seconds using one-to-three word queries and replies about motion and orientation. In our third study, Ss were rotated off-center at resultant gravitoinertial force angles of 45° or 60° in tangential-facing and in center-facing orientations. Subjects gave dynamic estimates of the perceived earth horizontal using a line of light and also provided retrospective verbal estimates of tilt.

RESULTS

Subjects tended to underestimate the resultant force angle in all measures during linear and angular oscillation. However, subjects came closer to accurately estimating the resultant force vector with some methods than others. The most to least accurate methods were: retrospective verbal report, subjective vertical tracking, laser retrospective horizon tracking, and laser concurrent tracking. For eliciting responses regarding movement illusions in our first two studies, verbal subjective reporting was the most consistent measure. Subjects' dynamic estimates during off-center rotation in two tangential headings were eventually tilted by about the same amount as the resultant force angle, but Ss tended to underestimate the resultant force angle during center-facing runs. In general, verbal and line-of-light estimates were well correlated for the center-facing stimulus and both tended to lag behind the stimulus during initial acceleration.

CONCLUSION

We conclude that the psychophysical method one employs to estimate orientation perceptions is important to the findings obtained. Different measures are appropriate to different stimuli and, indeed, may assess different aspects of an individual's orientation system. Attempts to standardize measures across studies must take this into account. While much of our data confirm early perceptual findings, the *dynamics* of tilt perception are a relatively unstudied aspect of the data that yield new interpretations. We will discuss our interpretations and their implications for the design of multimodal (visual, tactile, auditory) flight displays.

THE SOPITE SYNDROME REVISITED: DROWSINESS AND MOOD CHANGES IN STUDENT AVIATORS

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INTRODUCTION

Graybiel and Knepton coined the term *Sopite Syndrome* more than 20 years ago to describe the extreme drowsiness and mood depression they saw in subjects riding aboard the Pensacola Slow Rotation Room. They observed the syndrome even in subjects who had otherwise adapted to the motion and no longer experienced nausea. This motion-related syndrome has gone largely unexplored in recent years; we are initiating research into the Sopite Syndrome and seeking to determine its incidence in situations relevant to aerospace training and operations.

METHODS

We surveyed 1,945 aviation students who trained aboard the Multi-Station Disorientation Demonstrator (MSDD) and 40 airsick students referred to the Self-Paced Airsickness Desensitization Program (SPAD). These two studies are described below:

1) The MSDD consists of a vection projector and 10 capsules that rotate off-center. We queried each student's symptoms before, during, and after a 15-min MSDD training session. MSDD Survey #1 (n = 1585) was open-ended and relied upon the student to recall his specific symptoms. We looked for post-hoc evidence of the Sopite Syndrome (ie., motion-induced drowsiness increases and/or the appearance of unusual mood states defined by Graybiel and Knepton). MSDD Survey #2 (n = 360) was designed to yield a better estimate of drowsiness (the cardinal symptom of Sopite). We scored drowsiness using the Stanford Sleepiness Scale (1 = wide awake; 7 = falling asleep); motion sickness (MS) was scored similarly (1 = no symptoms, 7 = extreme discomfort). An increase over the baseline rating was counted as a possible incidence of MS or Sopite in that individual.

2) Student aviators who got airsick during their initial training flights were referred to the SPAD for treatment, many of whom were successfully returned to flight training afterwards. The SPAD required the participant to adapt to repeated head movements in four directions during gradually increasing rates of on-center rotation. Our SPAD Survey (n = 40, still ongoing) consisted of a battery of six different scales designed to detect changes in arousal and affect that could be indicative of the Sopite Syndrome. Incidence of Sopite was defined and coded using a similar strategy to MSDD Survey #2.

RESULTS

	MSDD Survey #1	**MSDD Survey #2**	**SPAD Survey**
Sopite frequency	3.7% of all students	28% of all students	77% of all students
Freq. of Sopite w/o other symptoms	19% of subgroup above	21% of subgroup above	3% of subgroup above

CONCLUSIONS

Our research has two main implications: (a) The Sopite Syndrome occurs frequently enough in two different motion environments to warrant further consideration; (b) the Sopite Syndrome appears to be the sole manifestation of motion sickness for some individuals. We conclude that this motion-related syndrome represents a poorly understood threat to performance that is not presently accounted for in most studies of sleep and fatigue during aerospace operations.