Tuesday, June 10

5/2-54
073743

Session TP2
Room 2
2:30 - 5:30 p.m.

Human Factors Research Under Ground-Based and Space Conditions - 1

HUMAN FACTORS ENGINEERING OF THE INTERNATIONAL SPACE STATION HUMAN RESEARCH FACILITY

Barbara Woolford
Flight Crew Support Division, Johnson Space Center,Houston, TX 77058

INTRODUCTION

The Human Research Facility (HRF) is a collection of two to four racks of equipment to be flown on the International Space Station (ISS) containing the baasic equipment necessary for virtually all research with human subjects. This equipment will be used by investigators and crews not yet selected, for the duration of the life of ISS. Since neither science users nor crew operators and subjects will be known during the development of the hardware, the HRF project included human factors engineers as an integral part of the design team from the earliest stages. The human factors engineers' role was to ensure the usability and maintainability of the equipment over the life of the HRF.

APPROACH

This paper describes the types of equipment evaluated and the human factors engineering techniques used for these various types. It addresses sources of data used for anticipating requirements when the ISS program has not completed its requirements development; types of evaluations performed, from analysis of drawings to evaluations in zero-gravity, and their relative cost effectiveness; and the process of integrating human factors engineers into design teams not accustomed to interacting with engineers from this field.

Critical human factors issues identified in working with the design teams are identified, and examples of evaluation methods and results are presented. Cases where broad guidelines or requirements must be provided are illustrated, and compared with situations where item-by-item analysis and inputs are necessary.

A description of the human factors issues unique to space research equipment is also given, with illustrations representing types of equipment ranging from computer workstations and interface hardware to body-worn sensors and data collection systems.

CONCLUSIONS

Lessons learned in the first eighteen months of this project show how space human factors engineers can provide cost-effective services to design teams which have never included human factors experts before.

STRUCTURED METHODS FOR IDENTIFYING AND CORRECTING POTENTIAL HUMAN ERRORS IN SPACE OPERATIONS

W.R. Nelson, L.N. Haney, L.T. Ostrom, and R.E. Richards
Idaho National Engineering Laboratory, Lockheed Martin Idaho Technologies,
P.O. Box 1625, Idaho Falls ID, 83415-3855

INTRODUCTION

Near and long term space operations will be highly dependent on human participation to ensure their success. Along with their significant capabilities to perform space operations and to diagnose and correct malfunctions when they occur, humans also come with a propensity to commit errors. Human errors have been identified as the source of approximately 60% of the incidents and accidents that occur in commercial aviation. It can be assumed that large numbers of human errors occur in space operations as well, even though in most cases the redundancies and diversities built into the design of space systems prevent the errors from leading to serious consequences. In addition, when it is acknowledged that many system failures (such as the Challenger accident) have their roots in human errors that occur in the design phase, it becomes apparent that the identification and elimination of potential human errors could significantly decrease the risks of space operations. This will become critical during the design of more complex and longer term missions such as the International Space Station and manned missions to Mars.

STRUCTURED METHODS TO IDENTIFY AND CORRECT HUMAN ERROR

The Idaho National Engineering Laboratory has worked for many years to develop and apply structured methods to identify and correct potential human errors. This work was initiated to support Probabilistic Risk Assessment (PRA) for the nuclear power industry. Methods of Human Reliability Analysis (HRA) have been adapted and extended so that potential human errors can be identified, their consequences in conjunction with other human errors and hardware failures can be assessed, and their relative contribution to overall system risk can be calculated. These methods have reached a state of maturity and acceptance in the commercial nuclear power industry.

During the last few years we have focused on adapting these tools to enhance their applicability as practical tools for system design, and to test their application to domains outside of nuclear power. Since 1994 we have performed research under the NASA Advanced Concepts Program in partnership with NASA Ames Research Center and the Boeing Commercial Airplane Group to develop methods and tools to apply human error analysis to the design of commercial transport aircraft. During the course of this program we have tested the applicability of human error analysis methods for application to maintenance tasks for commercial aviation. Based on this experience we are developing a software tool called THEA (Technique for Human Error Analysis) for use by airplane procedure developers and maintenance engineers. The tool is a structured approach for analyzing airplane maintenance tasks, identifying potential errors, identifying performance shaping factors that can influence errors, and identifying potential design or procedure changes that could reduce the likelihood for errors. The software has undergone testing at NASA and Boeing and will be available for release to the commercial aviation industry later this year.

We believe that our structured methods for human error analysis and our prototype software tool could be adapted for application to reduce the potential for human error in space operations. We are currently exploring the possibility to test our methods and tools for ground processing operations. If such an application proves successful, the methods could be adapted and applied to space operations in domains such as the Space Shuttle, Space Station, other potential manned space missions. We believe that such tools could contribute to minimize the potential for human errors in the design and operation of future space systems.

An Improved Procedure for Selecting Astronauts for Extended Space Missions

A. W. Holland[1], L. Galarza[2], R. D. Arvey[3] and K. D. Curtis[4]
[1]NASA Johnson Space Center, Houston; [2]Rice University, Houston; [3]University of Minnesota, Minneapolis; [4]Krug Life Sciences, Houston

This paper describes the model, methods and outcomes of a recent upgrade to the psychological selection process for NASA astronauts. A prototypical model, behaviorally-based and goal-directed, is presented which links mission results, individual and team behaviors, individual proficiencies, and various selection tools. The construct validity methodology by which the proficiencies and tools were chosen is also presented, including the methods for gathering expert and incumbent judgments and ratings, evaluating competing instruments, and archiving supporting information. New technology used in the data collection and archiving stages is described and evaluated. Finally, the strengths and weaknesses of the present system are discussed from the technical, logistical and organizational perspectives, with particular attention being paid to the development of experiential predictors and predictive validity data.

THE NASA PERFORMANCE ASSESSMENT WORKSTATION: COGNITIVE PERFORMANCE DURING HEAD-DOWN BEDREST

R.E. Schlegel*, R.L. Shehab*, S.G. Schiflett, D.R. Eddy*****

*** University of Oklahoma - Norman, OK, 73019 U.S.A.**
**** USAF Armstrong Laboratory - Brooks AFB, TX, 78235 U.S.A.**
***** NTI Incorporated - San Antonio, TX, 78239 U.S.A.**

The NASA Performance Assessment Workstation (PAWS) was used to assess cognitive performance changes in eight males subjected to seventeen days of 6-degree head-down bedrest. The PAWS uses six performance tasks to provide an assessment of directed and divided attention, spatial, mathematical, and memory skills, and tracking ability. Two subjective scales are also incorporated to assess overall fatigue and mood state. The PAWS tests were used to examine the impact of the space environment on flight crew performance on the Second International Microgravity Laboratory (IML-2) and on the Life and Microgravity Spacelab (LMS) space shuttle missions.

Following orientation and eight training trials, bedrest subjects completed sixteen additional practice trials on PAWS. The last eight practice trials and all bedrest trials were performed with subjects lying face-down on a gurney to minimize the potentially confounding effects of different subject positioning from practice to bedrest testing. During bedrest and recovery, subjects performed one session every other day, completing eight bedrest trials and four recovery trials.

In general, there was no apparent cumulative effect of bedrest. Following a short period of performance stabilization, a slight but steady trend of performance improvement was observed across all cognitive performance tasks. Performance improvement on the motor control tasks was more erratic, but much of this effect was attributed to differences in testing positions. For most tasks, this trend of performance improvement was enhanced during recovery. No statistically significant differences in performance were observed when comparing bedrest with the control (practice) period. Additionally, fatigue scores showed little change across all periods, with the exception of a dramatically lower fatigue level on the third recovery trial as the subjects readapted to a more "normal" living pattern.

COGNITIVE PERFORMANCE ABOARD THE LIFE AND MICROGRAVITY SPACELAB. D.R. Eddy, NTI, Inc., S.G. Schiflett, Armstrong Laboratory, R.E. Schlegel and R.L. Shehab, University of Oklahoma

INTRODUCTION. The impact of microgravity and other stressors related to space flight need to be quantified before long duration space flights are planned or attempted since countermeasures may be required. Quantitative measures of cognitive performance in-orbit can only be obtained on small numbers of subjects requiring special techniques to assess micro gravity effects. METHODS. Four astronauts completed 38 sessions of a 20-minute battery of six cognitive performance tests on a laptop computer. Twenty-four sessions were preflight, 9 sessions were in-orbit, and 5 sessions were postflight. Mathematical models were fit to each subject's preflight data for each of the 12 dependent variables. Expected values were generated from the models for in-orbit performance. The mathematical models of learning allowed the assessment of in-orbit effects while removing the expected, small effects of continued performance improvement. The models were linearized to allow the computation of a 95% confidence interval for in-orbit predicted values. RESULTS. Of the 48 data sets (4 subjects, 12 dependent measures), all were well fit by models, $p<.05$. Of those, 27 showed an in-orbit effect. The following tests showed degradation in at least one variable in three subjects: mathematical processing, spatial perception, and task switching. All subjects were degraded in two or more tasks. CONCLUSIONS. Although performance was found to be degraded, the factors causing the deterioration can not be determined from these preliminary results. Ongoing analysis of corresponding subjective fatigue scores and mood state data may explain performance degradations. Additional research involving appropriate ground control groups is required before concluding that microgravity is a determinant of degraded performance.

PSYCHOPHYSIOLOGICAL REACTIVITY UNDER MIR-SIMULATION AND REAL MICRO-G

B. Johannes[1], V.P.Salnitski[2], V.Korsun[3], A.J.Kaleri[4], K.Kirsch[1], O.I.Schewtschenko[2], F.Fischer[1], A.V.Dudukin[2], C.Gunga[1],
[1] Free University Berlin, Dept. of Physiology, [2] Institute of Biomedical Problems Moscow, [3]Starcity,
[4] RKK Energia

INTRODUCTION

Psychophysiological reactivity to standardized mental stressors is known to be individually very different but relatively stable under comparably conditions. Knowing the influence of extreme stress conditions like long-term isolation and long-term micro-g on the healthy human organism is expected to explain abnormal mechanisms of psychological stress. The workability of special operators under extreme conditions often depends more on the psychological than the physical state. For the development of individual countermeasures it is necessary to assess the individual reactivity type and its changes. During two long-term MIR-simulation studies in IBMP Moscow (HUBES, EKOPSI-95) hard- and software were tested and finally designed to assess individual reactions. Within the russian medical scientific space program russian cosmonauts are running such an experiment on board MIR station on the system NEUROLAB-B.

METHODS

A set of noninvasive physiological measurements was used to describe the state of the autonomic nervous system, cardiovascular system and central nervous system (EEG/AEP, EOG, ECG, respiration, EMG, blood pressure, puls transition time, skin conductance, periphere skin temperature, voice frequencies). The experimental procedure induced a series of changes between mental loaded activity and tranquil relaxation by a word recognition controlled software using multimedia features. The statistical analysis focused on the changes of each physiological channel, induced by the changing challenges. By means of a discriminant function with selected physiological parameters based on data of former clinical studies in Berlin/Germany the subjects were grouped into four different types of psychophysiological reactivity. These different regulation types were correlated with voice reactive, autonomic reactive, cardiovascular reactive and hypertensive subjects.

RESULTS

Considering only voice reaction types during the HUBES study we found different changes for the three subjects during the timeline but a comman final reaction type for all of them. During EKOPSI-95 the first time all physiological data were available in a fully by the subject self controlled experiment. One subject consisted all the time on one regulation type the other both switched between two types but without a significant tendency in time. These subjects also showed the same common final voice reaction type as the HUBES subjects but different „ways“ to it. The preflight data of the investigated eight russian cosmonauts for the 22. and 23. MIR-mission showed excelent quality. Two inflight experiments were run by both cosmonauts until now. The results from inflight and postflight experiments of MIR-mission 22 will be available at presentation.

CONCLUSIONS

The first experiments demonstrated that it is possible to run very complex psychophysiological experiments by trained subjects themselfes. The stability of this first statistical approach to classify psychophysiological reactivity is good. Further developement of these methods will lead to even better assessments of physiological regulation types. This diagnostical classification will improve the estimation of the psychophysiological state of operators under long-term isolated conditions and lead to new preventive therapeutical possibilities.