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MENTAL WORKLOAD AND PERFORMANCE EXPERIMENT (15-IML-1)

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Whether on Earth or in space, people tend to work more productively in settings designed for efficiency and comfort. Because comfortable and stress-free working environments enhance performance and contribute to congenial relationships among co-workers, the living and working arrangements for spacecraft to be used for missions lasting months or years assume particular importance. The Mental Workload and Performance Experiment (MWPE), in part, examines the appropriate design of workstations for performance of various tasks in microgravity, by providing a variable-configuration workstation that may be adjusted by the astronauts.

The workload and stress associated with space flight, along with direct effects of microgravity and adaptation, may also act to reduce the on-orbit performance of astronauts. It is important to quantify any such effects for the sake of planning and scheduling on-orbit astronaut activities. Since Space Station crew operations will require a great deal of computer interaction, MWPE includes an interactive experiment to be performed on a GRiD 1530 portable microcomputer by each of four astronauts. The experimental task is designed to test both cognitive and motor performance through a combination of accepted Fitts and Sternberg tasks. On-orbit performance will be compared to baseline performance measured during pre-flight and post-flight experiment sessions.

The importance of microgravity workstation design is due to the effect of weightlessness of body dynamics and neuromuscular control. Several experiments have indicated (Watt et al., 1985) that equilibrium limb positions are determine by balanced action of agonist-antagonist muscle pairs. A relaxed body position therefore corresponds to the balance of muscle pairs in a relaxed condition: on Earth this position is further influenced by the participation of gravitational forces in the balance. The upright, standing Earth-based posture, for example, is aided by a forward moment induced by gravity about the ankle joints, that helps resist the substantial moment that is imposed by the strong extensor muscles in the calf even when relaxed. Similar gravitational effects help straighten the knees and waist. Earth-based workstations, and the Spacelab, are designed to accommodate the upright, one-gravity posture.

In microgravity, by contrast, the strong calf and thigh muscles tend to keep the toes somewhat pointed and the knees and waist flexed (see Figure 1). With the feet planted on the floor adjacent to an equipment rack, therefore, a relaxed posture tilts the entire body well away from the rack, out of reach of controls and indicators. In order to work at a vertical rack in microgravity, therefore, an astronaut must strongly tense the ankle flexor, knee extensor, and back muscles in order to resist their strong antagonists and achieve an upright posture. This is very fatiguing over a long time.

The MWPE anthropometric experiments are conducted by having the astronauts use an adjustable workstation for a variety of on-orbit activities. The anthropometric workstation is attached to the Spacelab vertical handrails using a pair of articulated two-link arms that may be made rigid by hand-tightening a screw. The astronaut works at the workstation with his/her feet secured in foot loops, and positions and orients the anthropometric workstation in a way that is comfortable for the current task. Tasks to be performed at the anthropometric workstation are daily planning, a paperwork task; seed planting for the GPPF experiment, a characteristic hand-work task; and the MWPE computer interaction task. By observing the favored geometric relationships between the foot loops and the work surface of the anthropometric workstation, workstation design parameters may be determined for each type of task.

The MWPE interactive task combines memorization, short-term recall, and computer-screen target selection. The memory portion corresponds to the accepted Sternberg short-term memory task: it requires memorizing a set of one, two, four, or seven letters that are presented on the computer screen (see Figure 2). Once the subject has memorized the letters, he/she continues by striking the return key at the computer keyboard. A circular array of eight targets then appears on the screen, each target labeled with a single letter (Figure 3). Exactly one of these letters belongs to the memory set, and the subject is required to find the target labeled with that letter: the time required to do so is called the reaction time. Finding the target completes the Sternberg portion of the task.

The variety of memory set sizes (one, two, four, seven) presents the subject with a variety of levels of difficulty in the Sternberg position of the task. The subject's reaction time is taken as a measure of basic cognitive performance under the prevailing conditions. The Sternberg data-analysis paradigm models the reaction time as consisting of a constant delay time, plus a component proportional to the index of difficulty which equals the log to the base two of the memory set size. This paradigm provides a convenient parameterization for analyzing reaction time that is well founded in performance-measurement literature. The varying cognitive challenges also offer the chance to detect and characterize any patterns of performance degradation on orbit.

The Fitts task focuses on motor control, or the speed with which the subject is able to move and control an on-screen cursor. The cursor must be moved to the target selected during the Sternberg task, using one of three computer input devices: it is the beginning of this motion that marks the end of the reaction-time period. The Fittts movement time is recorded from the first cursor motion until the cursor is settled within the correct target square.

The cursor positioning motor-control challenge to the subject is varied by changing target arrangements, input devices, and motion directions. Both the target size and the distance to travel to the target vary. In addition, the difficulty of traveling to a particular target depends on the direction of travel. Most significantly, the input devices themselves vary in difficulty of use:

the joystick is a rate-controlling device and is rather more difficult to control than the position-controlling trackball. The keyboard provides a third control mode, using arrow keys to move the cursor about on the screen. As motor control and hand-eye coordination may be influenced by the on-orbit environment, either indirectly through fatigue and disorientation or directly through adaptation to microgravity, the cursor-control component provides a means of detecting such effects.

Experimental data collection for the anthropometric portion of the Mental Workload and Performance Experiment will be by analysis of videotapes of astronauts using the MWPE workstation on orbit. By comparing on-orbit video images of the workstation with images taken on the ground of the workstation surroundings, it will be possible to determine the selected configurations and to correlate them to the corresponding tasks. Astronaut comments will be useful as well in assessing the relative comfort and usefulness of workstation configurations.

The software used for the GRiD computer interaction experiments places the resulting data on computer diskettes for return to the ground for processing. In addition to reaction and movement times the software records the time required for the subject to memorize each data set, the time required for the subject to settle on the correct target, and the initial motion direction of the target cursor. These quantities allow additional flexibility of analysis of subject performance.

The results of the MWPE experiment are intended to be useful to Space Station Freedom designers and planners in creating effective, comfortable work environments for the crew members and in anticipating and planning for astronaut productivity on orbit. It is very important to understand astronaut on-orbit performance, so that systems and procedures may be developed that are realistic and that do not overload or under-utilize crew members. MWPE also gives researchers a start at investigating fundamental effects of microgravity and microgravity adaptation of crew members on cognitive and motor performance.

References

Watt, D.G.D., Money, K. E., Bondar, E. L., Thirsk, R. B., Garneau, M., Scully-Power, P. (1985), Canadian medical experiments on shuttle flight 41-G, Canad Aeronautics Space J 31:215-226.

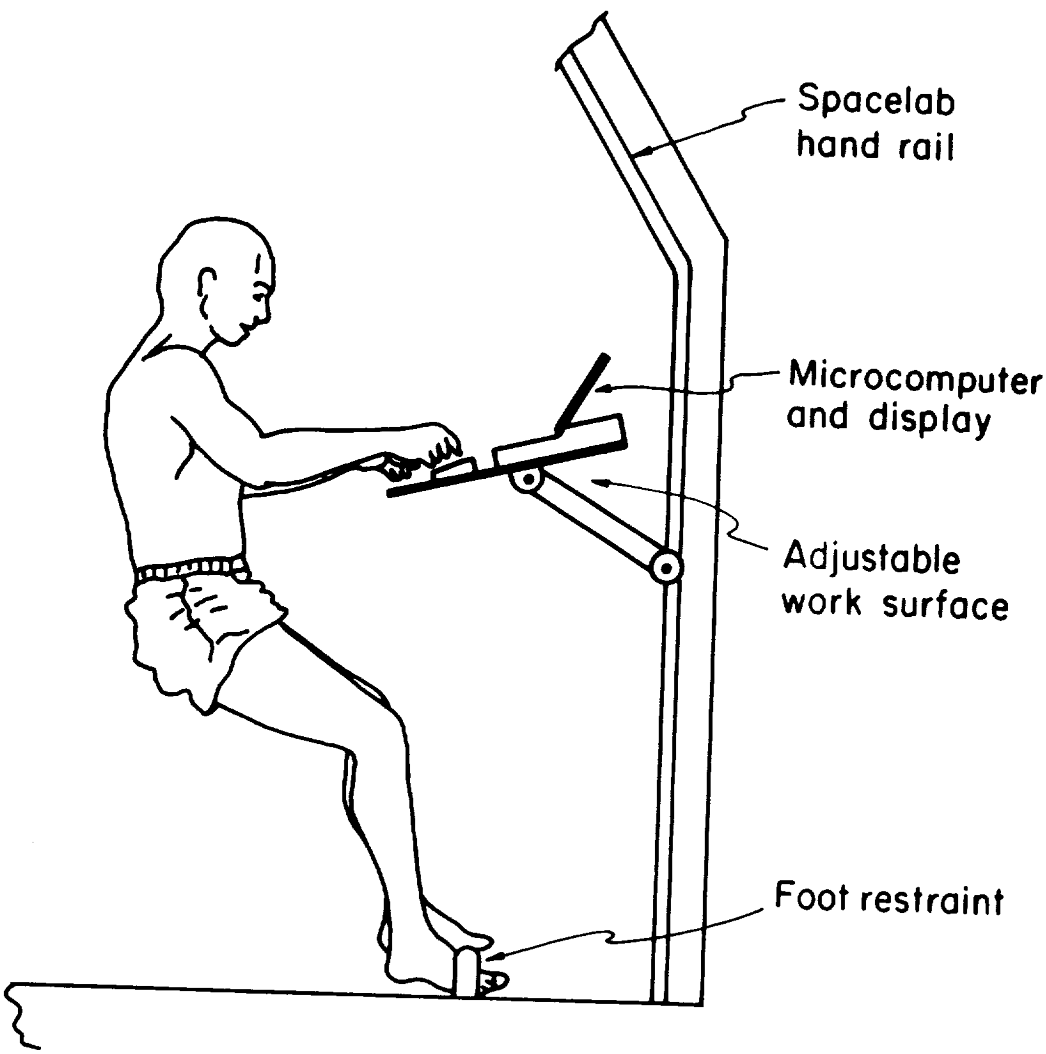
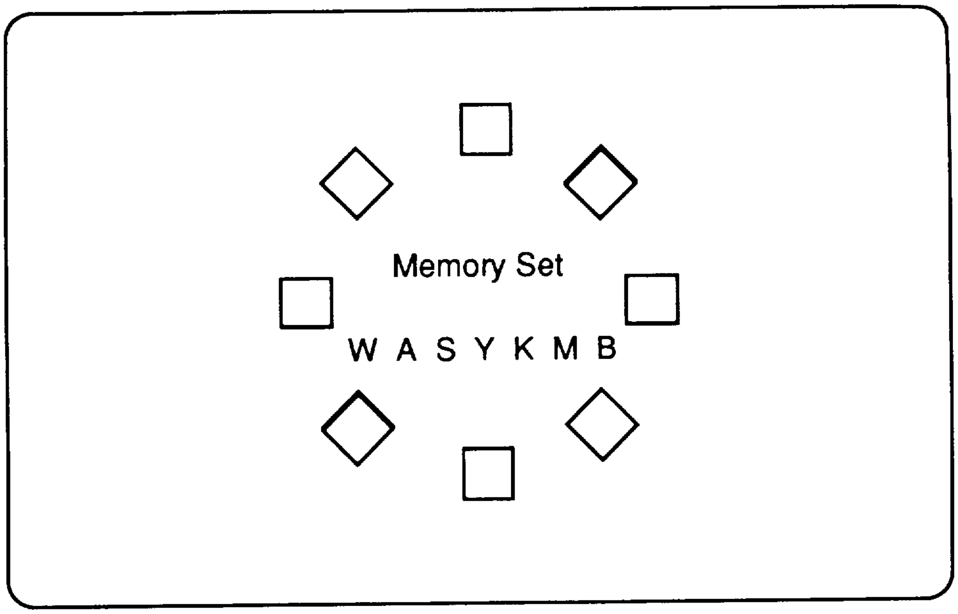
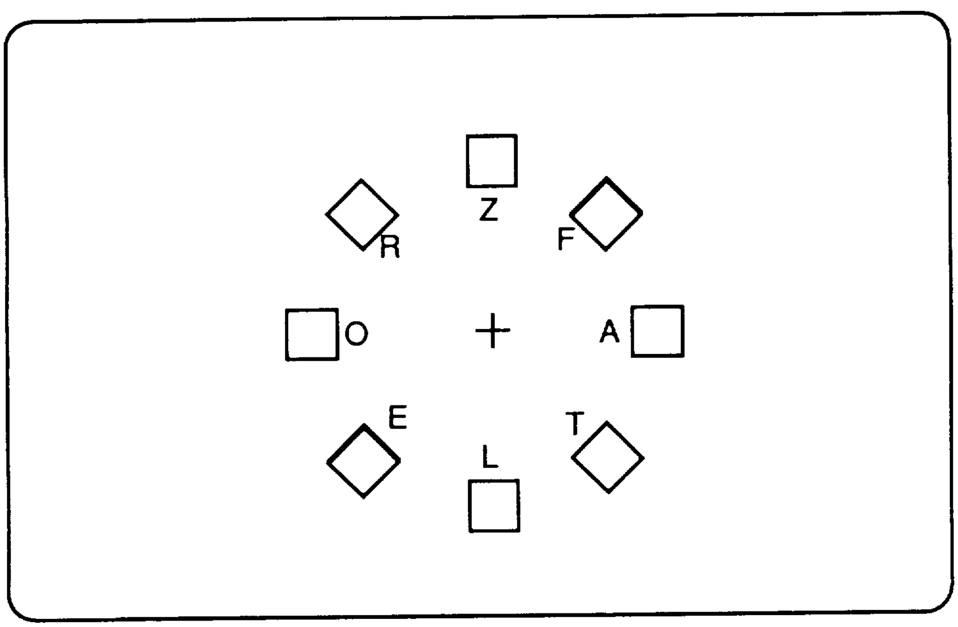


Figure 1. MWPE Deployed in Spacelab.



Display 1: Memory set display on computer screen.



Display 2: Target acquisiton display on computer screen.

Figure 2. Computer Screen Displays for the Mental Workload and Performance Experiment.