Evaluation of Hands-Free Devices for the Display of Maintenance Procedures

Ronald B. Hoffman, Ph.D., MEI Technologies
Harry Litaker, Jr., Lockheed Martin
Jody Solem, Lockheed Martin
Kritina Holden, Ph.D., Lockheed Martin
Evan Twyford, MEI Technologies
Carl Conlee, MEI Technologies
Mihriban Whitmore, Ph.D., NASA Johnson Space Center

Over the past year, NASA's focus has turned to crewed long duration and exploration missions. On these journeys, crewmembers will be required to execute thousands of procedures to maintain life support systems, check out space suits, conduct science experiments, and perform medical exams. To support the many complex tasks crewmembers undertake in microgravity, NASA is interested in providing crewmembers a hands-free work environment to promote more efficient operations. The overarching objective is to allow crewmembers to use both of their hands for tasks related to their mission, versus holding a paper manual or interacting with a display. The use of advanced, hands-free tools will undoubtedly make the crewmembers' task easier, but they can also add to overall task complexity if not properly designed. A leading candidate technology for supporting a hands-free environment is the Head-Mounted Display (HMD). A more recent technology (e-book reader) that could be easily temp-stowed near the work area is also a potential hands-free solution.

Previous work at NASA involved the evaluation of several commercially available HMDs for visual quality, comfort, and fit, as well as suitability for use in microgravity. Based on results from this work, three HMDs were selected for further evaluation (along with an e-book reader), using International Space Station (ISS)-like maintenance procedures. Two evaluations were conducted in the Space Station Mockup and Trainer Facility (SSMTF) located at the NASA Johnson Space Center (building 9). The SSMTF is a full scale, medium fidelity replica of the pressurized portions of the ISS. It supports crew training such as ingress and egress, habitability, and emergency procedures.

In each of the two evaluations, the participants performed two maintenance procedures. One maintenance procedure involved inspecting air filters in a life support system and replacing them with a clean filter if one were found to be contaminated. The second maintenance procedure focused on working in a confined space; specifically, pulling down a rack to inspect wiring configurations, and rewiring in a different pattern. The maintenance procedures were selected to assess mobility, tool use, and access to multiple document sources during task performance. That is, the participant had to move from rack to rack, use a wrench, a camera, etc., replace components, and refer to diagrams to complete tasks. A constraint was imposed that the ISS-like format of the procedures was to be retained, and not modified or optimized for the electronic device ("plug and play" approach). This was based on future plans to test with real procedures on ISS.

The first evaluation compared three commercial HMDs. In this evaluation, a conflict surfaced between display size, visual surround, and stability. Although some participants preferred a larger and crisper display area for presentation of the procedures, a clear need surfaced for being able to see the visual surround (of the work environment) with the eye that was reading the text instructions. There has been limited research that focuses on optimum display size for an HMD and how different display techniques affect user performance. Although there are some investigators that have suggested that HMDs are unsuitable for individuals operating in dynamic settings (e.g., moving vehicles), their results suggest that these displays are usable when the background is static (as in the procedures in this study). Overlapping images for both eyes were more of a problem when the near-eye display filled the field of view display for that eye. In addition, the stability of the display was important for operational use. Potential human factors issues to consider when refining the design of the HMD as derived from this evaluation include:

- Ability to view surrounding work area
- Comfort of head mount
- Stability of the HMD display
- Ease of adjustment of HMD display
- Intuitiveness of the cursor control mechanism

In the second evaluation, the best HMD from evaluation one (in terms of stability and display size) was compared against the current ISS maintenance procedure methodology (a laptop). Another possible technology solution, the e-book reader, was also included in the evaluation. A key observation from the evaluation was that each device influenced the way that participants performed the maintenance procedures task. That is, for the current method of using the laptop in the simulated ISS module, the participant had to continually move back and forth between the work area and the laptop, sometimes carrying material back to the computer display (Figure 1). The HMD permitted the participant to move into the work area, and work at the same time as reading procedural steps (Figure 2). Similarly, with the e-book reader, the participant carried the device, attached it near the work area (Velcro strips were available throughout), and referred back to the e-book display while working at the location (Figure 3). Both the HMD and e-book reader provided a better economy of motion in performing the task than the current laptop method.

Portability was a benefit of both the HMD and the e-book reader, as compared to the laptop. In addition, the full page of procedures in the e-book reader was much preferred to the display of scrolling procedures in the HMD. This was surprising since others have shown that the small monocular type of HMD display has minimal impact on visual fields, making them a reasonable choice to wear in non-immersive conditions with training. Furthermore, the larger displays of both the e-book reader and the laptop, with a larger information concentration, were influential in participants ranking the HMD below the e-book reader and laptop in terms of preference.

Additional evaluations are in progress to further understand the advantages and disadvantages of HMDs and other hand-free technologies for presenting maintenance procedures. The information obtained from these evaluations will be important in the development of hands-free technology requirements for future exploration missions.