Technology the Equalizer: Can it be Used to Improve Novice Inspection Performance?

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Abstract

Previous research indicates that as much as 90% of aircraft inspection is visual. Hence, where inspectors look is critical, potentially impacting inspection performance. Moreover, it has been shown that there are vast differences in performance between experienced and novice inspectors. Training on the task leads to superior coverage of the search area, better detection of defects, and improved efficiency and effectiveness. Providing this training, thereby improving the performance of novice inspectors, is the primary focus of this study. The research describes the virtual reality inspection environment and studies currently underway at the Advanced Technology Systems Laboratory (ATSL) at Clemson University in South Carolina. The studies funded by NASA are focused on evaluating alternate feedback and feedforward training strategies in improving aircraft inspection performance.

1 Introduction

Aircraft inspection and maintenance are an essential part of a safe, reliable air transportation system. Training has been identified as the primary intervention strategy in improving in section performance (Gramopadhye, et al., 1998). If training is to be useful, it is clear that inspectors need to be provided with training tools to help enhance their inspection skills. Existing training for inspectors in the aircraft maintenance environment tends to be mostly on-the-job (OJT). Nevertheless, this may not be the best method of instruction (Latorella et al., 1992). For example, in OJT feedback may be infrequent, unmethodical, and/or delayed.

Over the past decade, instructional technologists have developed numerous technology-based devices with the promise of improved efficiency and effectiveness, ushering in a revolution in training. Such training devices are being applied to a variety of technical training applications, including computer-based simulation, interactive videodiscs, and other derivatives of computer-based applications; and technology-based delivery systems such as computer-aided instruction, computer-based multi-media training and intelligent tutoring systems are already being used today. In addition, the compact disc read only memory (CD-ROM) and digital video interactive (DVI) are two technologies that will provide "multi-media" training systems for the future. The use of such technology, specifically computer-based simulators for aircraft inspection maintenance, has a short but rich history (Latorella et al., 1992; Gramopadhye et al., 1997; Blackmon et al., 1996; Nickles et al., 2001), the most advanced and recent example being the Automated System of Self Instruction for Specialized Training (ASSIST), a training program developed using task analytic methodology and featuring a PC-based aircraft inspection simulator (Gramopadhye et al., 2000). The results of the follow-up study conducted to evaluate the usefulness and transfer effects of ASSIST were encouraging with respect to the effectiveness of computer-based inspection training, specifically in improving performance (Gramopadhye et al., 1998).

Despite their advantages, existing multimedia-based technology solutions, including low fidelity simulators like ASSIST, still lack realism as most of these tools use only two-dimensional sectional images of airframe structures and, therefore, do not provide a holistic view of the airframe structure and the complex maintenance/inspection environment. More importantly, the technicians are not immersed in the environment, and, hence, they do not get the same look and feel of inspecting/maintaining a wide-bodied aircraft. To address these limitations, VR technology has been proposed as a solution (Vora et al., 2001).

Using VR, one can more accurately represent the complex aircraft inspection and maintenance situation, enabling students to experience the real hangar-floor environment. The instructor can create various inspection and maintenance scenarios by manipulating various parameters – for example, defect types, defect mix, defect severity, defect location, defect cues -- reflective of those experienced by a mechanic in the aircraft maintenance hangar environment. As a result, students can inspect airframe structure as they would in the real world and initiate appropriate maintenance action based on their knowledge of airframe structures and information resources such as on-line manuals, airworthiness directives, etc. Their performance in tackling these scenarios can be tracked in real-time with the potential for immediate feedback and active learning. Furthermore, instructors can use a progressive-parts approach based on the adaptive needs of the student, or instruction can be delivered asynchronously based on the availability and schedules of the student. The result is an innovative curriculum application, one in which the student will be able to visualize and test the information that is presented, internalizing the lesson. Students will be able to grasp the links between various visual cues presented, the need for specific inspection items and potential maintenance solutions. Repeated exposure to various scenarios along with classroom teaching will help them link theoretical scientific knowledge, for example, physical and chemical characteristics of structures, to various engineering solutions. In response, research efforts at the Advanced Technology System Laboratory (ATSL) at Clemson University have focused on developing the VR simulator for aircraft inspection training.

2 Development of the VR Environment

The development of the VR environment was based on a detailed task analytic methodology (Duchowski et al., 2001). Data on aircraft inspection activity was collected through observations, interviewing, shadowing, and digital recording (using video and still images) techniques. More detail on the task description and task analytical methodology can be found in Duchowski et al. (2001).Various scenarios were developed which were representative of those would occur in the real world environment. A library of defects was developed occurring at various severity and locations. The following defects were modelled: corrosion, crack and broken conduits. By manipulating the type, severity, location and defect mix; experimenters can now create airframe structures that can be used for running controlled studies.

3 The VR Environment

Our operational and deployable VR inspection simulator features a binocular eye tracker built into the system's Head Mounted Display (HMD), which allows the recording of the user's dynamic point of regard within the virtual environment (Figure 1a) (Duchowski et al., 2001). User gaze direction, as well as head position and orientation, are tracked to enable navigation and post-immersive examination of the user's overt spatial-temporal focus of attention while immersed in the environment. Tracking routines deliver helmet position and orientation in real-time, both of which are then used provide updated images to the HMD. User gaze direction is tracked in real-time (Figure 1b), along with calculated gaze/polygon intersections, for subsequent off-line analysis and comparison with stored locations of artificially generated defects in the inspection environment (Duchowski et al., 2002).

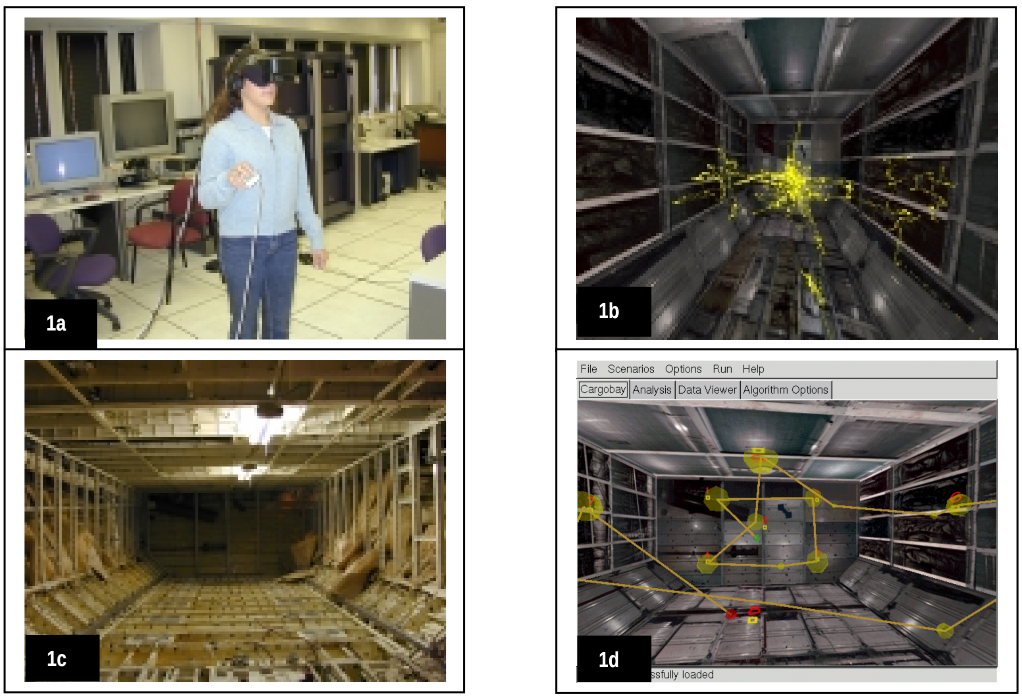

Figure 1: (1a) User immersed in VE, (1b) Real time gaze tracking in VR, (1c) Physical aircraft cargo bay, (1d) Captured fixation in virtual environment

The goal of the construction of the virtual environment is to match the appearance of the physical environment, similar to the example shown in Figure 1c (Vora et al., 2001). Eye movements, following fixation analysis, captured in the existing prototype VR environment are shown in Figure 1d. During immersion, users have access to tools similar to those used by a technician on the aircraft hangar floor (e.g., flashlight, mirror), albeit these are virtual in our environment. The system captures process data (eye movements of the subjects as seen in Figure 1d) and performance data (speed and accuracy) for use as feedback to the subjects. Several defect scenarios have now been developed (e.g., enabling visual search for corrosion, cracks, broken conduits), augmented with user-adjustable parameters. The graphical user interface facilitates on-line user immersion and off-line eye movement analysis.

Since initial development, we have successfully migrated from primary supercomputer rendering engine (a dual-rack, dual-pipe, SGI Onyx2® InfiniteReality™ system with 8 raster managers and 8 MIPS® R10000™ processors) to a personal computer. Our PC platform, running Linux and equipped with an NVidia GeForce4 TI4600 graphics card, attains rendering performance comparable to our former SGI platform at a significant reduction in cost. Multi-modal hardware components include a binocular ISCAN eye tracker mounted within a Virtual Research V8 (high resolution) Head Mounted Display (HMD).

4 Description of Studies

The studies funded by NASA are focused on the evaluation of alternate feedback and feedforward strategies in improving inspection. The following is a description of two experiments underway.

Feedback information has had consistently positive results in all fields of human performance (Gramopadhye et al., 1997), provided that it is given in a timely and appropriate manner. Wiener (1975) has reviewed feedback in training for inspection vigilance and has found it universally beneficial. Traditional feedback provided to the inspector has been performance feedback (speed and accuracy). Another form of feedback is information on process/ measures (e.g., search strategies, eye-movements data). However, it is still unknown how process and performance feedback should be presented to the inspector and what would be the best forms (i.e., statistical and graphical) of presenting this information. Therefore, the primary objective of this study is to evaluate the effectiveness of alternate feedback strategies (process, performance, and combined) on visual search performance: speed, accuracy, and search strategies.

The use of prior information (feedforward) is known to affect inspection performance (McKernan, 1989). This information can consist of knowledge about defect characteristics (types, severity/criticality, and location) and the probability of these defects. Although several studies have been conducted that demonstrate the usefulness of feedforward as a training strategy there are certain research issues that need to be addressed. These issues include: what format should feedforward information be presented in, when should feedforward information be presented, and how much feedforward information should be presented. Hence, this study evaluates the effect of feedforward information in a simulated 3-dimensional environment by the use of virtual reality. A simulated aircraft cargo bay in which inspectors must locate and identify various types of defects is the simulated environment used for the study. The use of job-aiding tools (flashlight and mirror) in conjunction with feedforward information is also evaluated.

5 Discussion and Conclusions

The VR environment developed allows researchers to conduct off-line controlled studies, facilitating the collection of performance (e.g., speed and accuracy) and process measures data (e.g., eye-movements strategies). The results obtained from these studies can be used to understand different aspects of inspection performance. Earlier studies have shown good transfer effects between virtual environments and real-world environments (Vora et al., 2001) in aircraft inspection. The results of these studies will throw new light in the use of feedback and feedforward in improving inspection performance, which will ultimately improve safety. Moreover, using the VR environment, we will be able to train novice inspectors in where to look for defects, thereby bring their performance to that of experienced colleagues in a shorter time span.

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