COST EFFECTIVE VIRTUAL REALITY

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ABSTRACT

Air Education and Training Command (AETC) Studies and Analysis Squadron (SAS) in conjunction with the 363d Training Squadron (TRS) at Sheppard AFB, Texas, evaluated cost effective virtual reality (CEVR), an innovative application of virtual reality imaging without the headset. This Education and Training Technology Applications Program (ETTAP) funded initiative supports the Mark 84 Bomb portion of the Munitions Systems Apprentice course. The study focused on the effectiveness of CEVR as a supplement to individual training equipment. The initiative seeks to augment maintenance bay assembly and disassembly of munitions with group presentation of scanned real-world images. Constant assembly and disassembly of the training hardware causes wear and failure of the equipment. Further, it is difficult for students to adequately view parts and associated positions within the training equipment, resulting in less than optimum training. Finally, training with heavy munitions in the maintenance bay environment has inherent safety implications that use of VR may alleviate. CEVR mitigates some of the dangers and drawbacks of training with hardware.

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INTRODUCTION

Air Education and Training Command (AETC) Studies and Analysis Squadron (SAS) evaluated cost effective virtual reality (CEVR), an innovative application of 3D imaging. This Education and Training Technology Applications Program (ETTAP) initiative supports Mark 84 Bomb training by the 363 Training Squadron (TRS) at Sheppard AFB, Texas.

Previous Studies

Until recently, virtual reality in DoD training came in two varieties: desktop and fully immersive (Furness, 1986; Greene, 2001; Levinson, Tenney, Getty, & Pew, 1994; Zyda, Pratt, Falby, Lombardo, & Kelleher, 1994). Desktop consists of 3D graphics shown on a 2D screen and manipulated with a 2D mouse (Bolas, 1997). Fully immersive VR involves a head mounted display (HMD) and either gloves or pointer, giving the user a sense of "virtual presence" within a simulated environment (Sheridan, 1992). The problem with the desktop variety is that it removes the user's ability to perceive and manipulate 3D objects or obtain natural depth information (Bolas, 1997; Cochrane et al, 1997). The problem with fully immersive VR is the inconvenience and discomfort of the headset (Cochrane, Matthews, Cameron, & McCartney, 1997); user sickness from dizzying motions inside HMDs (Pfautz, 1997); and limited computational power, among other troubles (Pfautz, 1997).

Partially immersive VR is a third option that provides a 3D environment with some of the same factors as high-end VR but at a lower cost and without the HMD (Hardy, 2000). Largely confined to university labs and museums (Hardy, 2000), this new technology

mimics the expectations of the human visual system (Pfautz, 1997). Until now, the efficacy of partially immersive VR, or CEVR, training has neither been tried nor tested in DoD.

Background

Before CEVR, Mark 84 Bomb training consisted of lecture/demonstration methods with an associated hands-on lab. Demonstration was performed on munitions systems training equipment requiring repeated assembly and disassembly with resultant wear. Further, it was difficult for students to adequately view parts and associated positions within the training equipment, resulting in less than optimum training.

A particular problem with live bomb assembly was the safety hazard. Mishaps, while rare, have caused severe injury on occasion. Any acceptable substitute for live demonstration would help cut down the risk.

Virtual Reality (VR)

The concept of virtual reality in the AF training environment has been proven by the successful implementation of the F-15 Strike Eagle safe-for-maintenance trainer at Sheppard AFB, Texas. That project has basically saved the cost of an F-15E and the continuous associated logistics. The half-million dollar price tag for the fully immersive, head mounted display, virtual reality system was still expensive, and since it can train only one student at a time it would not be very efficient in a classroom

environment. CEVR seeks to employ similar technology but for one fourth (1/4) the cost.
This project demonstrates group virtual reality without the use of individual equipment. One problem with stereoscopic headset-based 3D training is the potential for severe disorientation that is observed when a student is first introduced to the environment. Many individuals never seem to get oriented. The group-based system should minimize and/or eliminate this disorientation problem.

Another drawback to fully immersive VR is that the images are graphic based (cartoons). CEVR is able to take real-world images and convert them to 3D. It is then possible to present equipment assembly and disassembly in the classroom rather than in a maintenance bay.

VR without Headsets

This is a demonstration of a new and innovative technology through the use of special monitors to present 3D images. Currently selling for about $1600, these commercially available 3D monitors enable students to see hologram type images without the use of specialized glasses or headsets. The monitors make use of synthetic stereopsis, in which the illusion of depth is achieved by the assimilation at brain level of two complete but slightly different images of a scene to the observer's two eyes. This new technology presents a different image of a subject to each eye without the use of head gear. The subject can be a real world image, and not just a cartoon.

This is accomplished through the use of a special backlight behind a liquid crystal display. The backlight generates a pattern of vertical lines, one behind every two columns of pixels. When a person sits in front of the display or in certain areas off to the sides, they see the lines through the odd columns with their left eye and through the even columns with their right eye. The person sees real depth (Figure 1).

Figure 1. Image on CEVR Monitor

Success in this arena could be the basis for real-time transmission of stereo-3D data over the existing video tele-conferencing systems.

Other advantages to this technology:

- One complete image allows the viewer's eye to focus at differing points in the image, just as with real-world scenes
- Viewer is not mechanically attached to the presentation equipment
- A process analogous to colorizing film permits conversion of existing 2D film and video libraries to real 3D imagery
- Eliminating the HMD frees the viewer from constraint. This problem has been a major impediment to the deployment of 3D
- Imagery can appear both behind the plane of the screen and out in front of the screen in free space
- Viewable depth is available to the viewer at several viewing angles
- Demonstration of 3D video projection may be possible with a more advanced version of the technology
- It allows the use of off-the-shelf VCRs and video switchers and use of digital effects generators without loss of depth.

DVD

Going from simple 3D graphics to full scale video requires considerable storage capacity. Stereoscopic 3D takes up twice as much data as 2D. A two and a half hour video demonstration would need to bestored on about 70 CD ROMs.
The same 3D video could be stored on two Digital Video Discs (DVD).

STUDY APPROACH

This study attempted to determine the feasibility of CEVR training in the Air Force.

In particular the study examined:

- Quality of the CEVR technology
- Instructor to trainee interaction
- Effectiveness of CEVR on job performance
- Cost effectiveness

Scope

Twenty minutes of group VR was introduced into the training of 904 fuze assembly for the Mark 84 Bomb. That training constitutes a portion of the Munitions Systems Apprentice course at Sheppard AFB, Texas.

Study Data

Experimental Data Five classes (54 students) made up the implementation test group. This number is sufficient to provide a basis for a valid trend analysis.

CEVR imaging was presented to students on two 18” screens to avoid disorientation associated with the HMD. Using the system was expected to improve visual presentation for students, yielding improved training while reducing wear on munitions training equipment.

Effectiveness was measured four ways. We collected student test scores, as well as student and instructor critiques. We measured student satisfaction with classroom training. Finally, an observer in the targeted block gathered data on student attentiveness. More effective classroom instruction should lead to higher test scores, more favorable critiques, greater satisfaction, and increased attention.

Baseline Data Five classes of 51 students who underwent munitions training prior to introduction of VR constitute the control group. The study compared their performance to that of the 54 in the experimental group.

STUDY RESULTS

Quality of the CEVR Technology

Three Presentations
The CEVR technology has successfully been implemented. Students are able to see three different types of VR: a single graphic representation of the 904 fuze, which students are able to move and manipulate with a PC mouse; an Audio Video Interleave (AVI) graphical playback clip; a video of an instructor assembling the 904 fuze and installing it in the Mark 84 Bomb.

The following figures are some of the views that CEVR displays. Figure 2 shows the explosive train aligning the detonator. Figures 3 and 4 show detailed views of the gears and rotors, respectively. Figure 5 shows Successful detonation. Figure 6, a frame from the live action video, shows fuze assembly by an instructor.

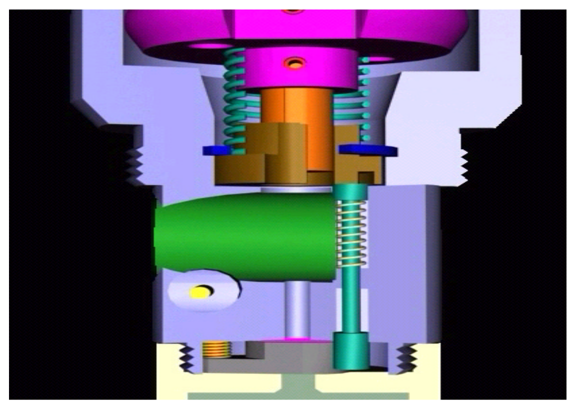


Figure 2. Explosive Train

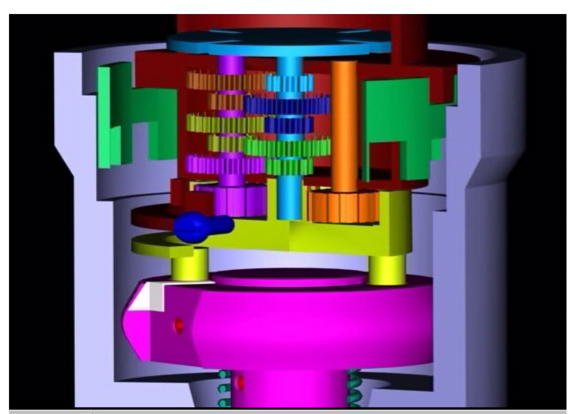


Figure 3. Gears

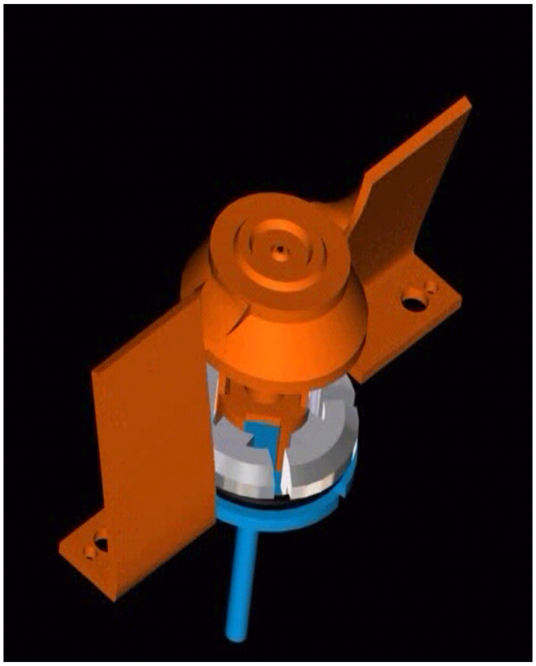


Figure 4. Rotor

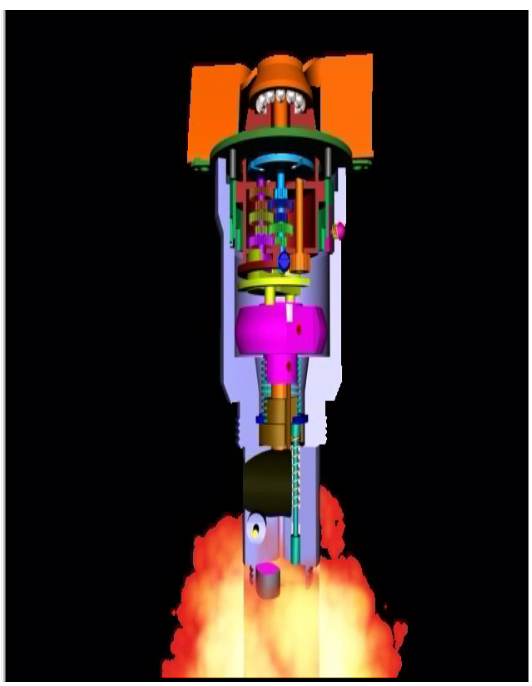


Figure 5. Detonation

Figure 6. Assembly

The graphics appear to be moving both inside and outside the plane of the monitor screen. The video has visual depth inside the screen only. During the video the instructor is able to demonstrate principles of assembly (little pieces to big pieces) and safety. All three CEVR presentations have smooth rotation of movement, with none of the flicker effect often observed with HMD VR.

VR Monitors

To our knowledge, only one company makes the super high resolution monitors that contain the technology to produce the kind of 3D VR effect employed in this study. The 2D resolution on these monitors is 1280 x 1024 pixels.

The VR monitors, along with the 700 MHz Pentium PCs that drive them, have the capacity to produce over 750,000 polygons, or 30 frames, per second, well above the 26 frames per second necessary to avoid choppy motion and the "sea sickness" that often results.

DVD

The video was successfully compressed into MPEG format onto DVD and downloaded onto classroom PCs.

Digital Camcorder

The study used Canon GL1 digital camcorders to record the video. An innovative approach was installing a "fire wire connector" directly from the camera to the PC hard drive, bypassing the computer's central processing unit. The end result was a high definition digital video, with no lost frames.

Problems with the CEVR Technology

This study has learned several lessons about obstacles that need to be surmounted in order to get CEVR to work. For example:

a. The capability of CEVR to train a classroom of students is limited by monitor size. The 18" monitors used in this study could effectively train no more than three students at a time.

b. Special care should be taken to ensure PC drivers for the DVD player are robust. Incompatibilities in a driver forced the transfer of MPEG files from the DVD onto the PC, in order to get it to play.

Instructor to Trainee Interaction

User Response

The instructors who saw the 904 fuze presentation reported that they were able to see critical internal operations of the mechanism for the first time. Until then, they hadn't realized how it worked.

Some of the students, on the other hand, complained about the clarity of the 3D. The resolution on the VR monitors in 3D mode is half as fine as in 2D mode, because VR basically splits each frame into two separate "fields." Students going from 2D to 3D were somewhat disappointed.

As an added measure of user response, this study distributed student feedback questionnaires. Results from the baseline (without CEVR) and experimental (with CEVR) groups who received munitions technical training appear on Tables 1 and 2.

The experimental group gave lower ratings on all five aspects of classroom training than did the baseline group.

Table 1. Baseline Group Satisfaction

Aspects of Classroom Training	***Not Very Satisfied***	***Very Satisfied***
Instructional Delivery	20	30
Subject Interest	21	29
Presentation/Visual Aids	19	30
Classroom Environment	27	24
Instructional Material	29	21

Table 2. Experimental Group Satisfaction

Aspects of Classroom Training	***Not Very Satisfied***	***Very Satisfied***
Instructional Delivery	39	15
Subject Interest	42	12
Presentation/Visual Aids	39	13
Classroom Environment	41	12
Instructional Material	40	14

A majority of baseline students were "very satisfied" with three out of five aspects of classroom training. By contrast, a majority of experimental students were not "very satisfied" with any of the five aspects of classroom training.

Student Attentiveness

An observer attended class during demonstration of 904 fuze assembly. He rated student attentiveness on a 27 point scale, broken into three major categories: "Display of Interest/Class Participation," "Facial Expressions," and "Posture/ Physical Demeanor." Table 3 outlines his main findings.

Table 3. Student Attentiveness

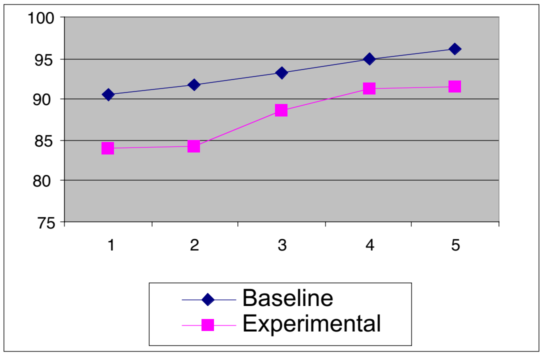
Attentiveness Categories	***Baseline Group***	***Experiment Group***
Main physical demeanor	Fidgeting	Military Posture
Main facial expression	Yawning	Alert
Main class participation	Asking Questions	Watchful

On the whole, the experimental students were more attentive than the baseline group, who displayed general signs of boredom.

Effectiveness of CEVR on Job Performance

The study looked at test scores for the 904 fuze assembly block. Results appear in Figure 7.

Figure 7. Average Class Test Scores



As Figure 7 shows, the five baseline classes scored consistently higher than the five experimental classes. The overall baseline average was 93.4 compared to 87.7 for the experimental students. In addition, four of the five baseline classes had a class average higher than that of all five of the experimental classes using CEVR.

Low student scores and low student satisfaction may go hand in hand. Both may relate to student complaints about the clarity of the CEVR images.

Cost Effectiveness

The Technical Package

As recently as five years ago, the technology employed in CEVR was so rare that it would have cost upwards of $1M to obtain. At that time the maximum capacity of the highest end workstation was 650,000 polygons per second. Today, the combination of the VR monitor, the digital camera, and the 700 MHz PC cost about $6000.

Sickness, Safety, Wear and Tear

Other types of costs, both human and financial, include sickness, safety, and wear and tear of equipment. None of the students got sick as a result of watching the demos. With over 30 frames per second to avoid flicker, and without HMDs to cause discomfort, CEVR averted one of the common scourges of VR. With no actual equipment, CEVR also eliminated the possibility of safety mishaps or wear and tear on the hardware.

SUMMARY

Several new Air Force weapon systems are presently coming into service in the near future. These systems will need to be incorporated into the Air Force formal training system. CEVR will not reduce blocks of instruction, but it may help ease the burden of this increased workload. Less equipment may have to be procured, maintained, or demonstrated in the lab; fewer safety measures may have to be taken. At the same time, students may see and understand mechanisms which even the real equipment would not show them.

On the positive side, CEVR technology works. The benefits to health, safety and equipment degradation are apparent. In addition, students using CEVR seem to be more attentive. On the negative side, student satisfaction and student test scores are consistently lower among those using CEVR than among those training on equipment alone. In particular, students complain about clarity. They have a hard time seeing the demonstrations.

The concept of virtual reality without headsets is not only promising but feasible. As the technology matures, CEVR may eventually benefit student test scores as much as it currently benefits classroom safety, health, and equipment maintenance.

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