APPLICATION OF A THREE-DIMENSIONAL TARGET DISPLAY FOR WEAPONS TRAINING

Albert Marshall
Edward Purvis
Ronald Wolff
Robert McCormack

Naval Training Systems Center

ABSTRACT

A 3-D large screen display for small arms and minor caliber weapons has been designed and the prototype will be displayed at the I/ITSEC 93 conference. The system provides interactive stereoscopic images of the environment and targets that virtually leap from a 100 inch diagonal video projection screen. The system uses switched LCD glasses, worn by the trainee, to convert video recorded from two separated video cameras and stored on video disk to 3-D like images. Three -Dimensional computer graphics objects are added to portray tracers and objects flying at the trainee. The prototype has been tested and the efficacy of the prototype is discussed. The use of a small motion platform with the system is also discussed.

ABOUT THE AUTHORS

Mr. Albert H. Marshall is a Team Leader / Electronics engineer in the Systems Integration Branch at the Naval Training System Center. He has specialized in developing weapon fire simulators using lasers, electro-optics, microcontrollers and video disk technology for twenty six years. He holds thirty U.S. patents. Mr. Marshall has a Masters Degree in both Physics and Electronics Engineering from Brown University and the University of Central Florida.

Mr. Edward J. Purvis is an Electronics Engineer in the Systems Integration Branch at the Naval Training Systems Center. He has specialized in developing weapon fire simulators using electro-optics, microprocessors, video processors, and graphics for nine years. He has a Masters Degree in Digital Electronics from the University of Central Florida.

Mr. Ronald S. Wolff is an Electronics Engineer in the Systems Integration Branch at the Naval Training Systems Center. He has worked extensively in Weapons Simulation Technology for the last seven years. Mr. Wolff has worked in system design and integration, analog design, electro-optics, microcontrollers, and sensor interfacing. Mr. Wolff has a Masters Degree in Electronics Engineering from the University of Central Florida.

Mr. Robert McCormack is an Electronics Engineer at the Naval Training Systems Center. He has specialized in developing weapon fire simulators. He has worked on computer program development and sensor interface to computers. Mr. McCormack graduated in 1985 from the University of Central Florida, where he is currently pursuing a Masters Degree in Computer Engineering.

INTRODUCTION

A successful training device creates a human trainer interface in which the device creates a sensory-immersing environment that interactively responds to and is controlled by the actions of the user. The creation of such an environment requires the immersion of your senses in a computer 3-D world to create the experience of actually "being there". What we hope to achieve is to create an environment real enough for you to suspend your disbelief during a period of time and make you feel you are actually facing a real world enemy. To create the desired sensory environment a large screen 3-D visual display system, interactive targets and computer controlled 3-D sound has been incorporated. The systems key attributes include:

(1) The environment is displayed in 3-D.

(2) A method to interactively remove aggressor targets which are hit as a training scenario progresses.

(3) A method which allows aggressor targets to engage and disable a trainee who does not take appropriate cover.

(4) A 3-D sound system.

Many simulator-based team trainers currently use technology which restricts realism in tactical training situations. It is anticipated that adding the 3-D will help to make the screen seem to disappear and make the trainee feel he is in the same environment as his enemy.

The prototype system developed at the Naval Training Systems Center will allow a trainee to practice and rehearse close combat training exercises such as SWAT operations with an unsurpassed level of realism and feedback in a 3-D environment. Typical events might include hostage rescue, security operations, shoot-no-shoot, ambush training situations and routine law enforcement operations.

Safety is also a concern during live fire training exercises. Since the trainer uses no live ammunition the dangers of an inadvertent weapon discharge or lead poisoning are eliminated entirely.

Much of the trainee performance data and feedback provided by the trainer is not available using live fire training. The prototype provides advantages over live actor force-on-force training in a number of critical areas. Reliability of scenario presentation is inherent in the simulator system, where as live actor based training introduces variability in the form of inconsistencies and other human errors. The prototype also provides extensive measurement of trainee behavior and achievement which can be used for feed-back and leads to objective fulfillment. Through controlled presentation of intelligent scenarios, the trainer provides more reliable decision making tactical situations than any current alternative.

"Build it and see what happens " is the maxim inventors have lived by for millennia. This new addition may possibly allow for effective and realistic training for military operations previously unobtainable through simulation. Will this technology allow us to better portray the real world and allow us to see and feel things not possible in the past ? We will discuss the prototype and results of the testing during the paper presentation.

DESCRIPTION OF THE SYSTEM

The system uses switched liquid crystal (LCD) glasses, worn by the trainees, to convert video recorded from two cameras and projected with different perspective views to form 3-D like images See Figure 1. Each camera views a different perspective because the video cameras used to record a scenario are offset horizontally from each other like the human eyes. The average separation distance of a persons eye is 2.5 inches The video scene taken with the left camera perspective is viewed by the left eye and the scene taken with the right camera perspective is viewed by the right eye. This video recording method presents the views a person sees with two separated eyes in the real world. Two different perspective viewpoints are synthesized by the brain to produce a stereoscopic 3-D like effect similar to the realism that the trainees experience in the real world.

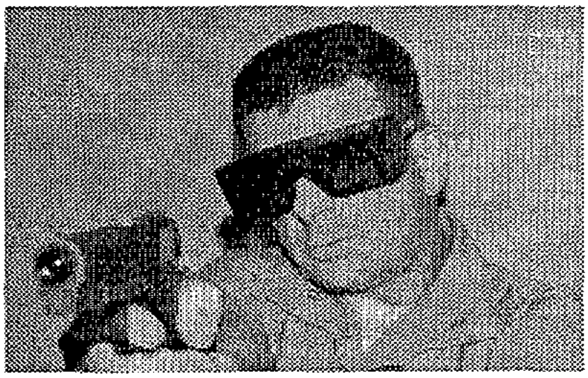


FIGURE 1. LCD GLASSES AND SIMULATED WEAPON

The human brain is the last link in this optical system because it converts the spatially separated video data into a stereoscopic 3-D experience for the trainee. The addition of depth cues add to the realism of the projected environment.

The hardware used for stereo video recording is shown in Figure 2. A view/record controller accepts the inputs from two genlocked cameras and converts them into a single signal. The signals from the two video cameras are stored in memory and operated on topologically to produce a side by side field format.

Each picture has 240 video lines per field in a four - fold interlace pattern. This pattern has the following sequence of fields: left (odd), right (odd), left (even), right (even), etc. The recorded signals are also indexed to allow the images to be later played back steroscopically. This signal is recorded by a single standard S-video recorder and later edited and recorded to a video disk. Scenario data is recorded in a stereo format by using two standard video cameras. The two cameras are mounted on a common base and aligned to be parallel and the optical axes are approximately 2.5 inches apart. Video camera lenses, focal lengths f-stops and color balances must be identical. The output of the dual s-video cameras is 60 fields per second 15.75 KHz signals. The view record controller takes the standard s video from the left and right cameras and produces a side by side format for recording on a standard S video recorder.

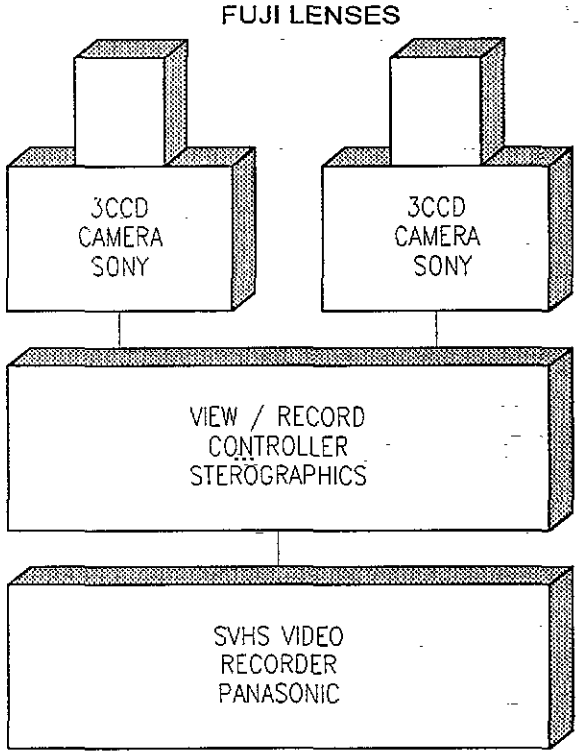


FIGURE 2. STEREO VIDEO RECORDER

The playback controller processes the stereoplexed signal to read out the sidefield lines in the odd and even sequence previously described. The video information is alternately projected at a 120 fields per second on the video screen. The Stereo Video playback block diagram is shown in Figure 3. If the trainee looks at the screen without shuttered glasses he sees what appears to be a double image. Using shuttered lenses the trainees left eye sees only the left image and the right eye the right image. Each successive field alternates from the left eye to the right eye. One eye is alternately shuttered while the other eye views the screen. The electro-optic shutters use switched liquid crystal lens materials that alternately render one lens clear and the other lens opaque.

Color, brightness and geometry of the two projected video perspectives must be identical or "eyestrain" results.

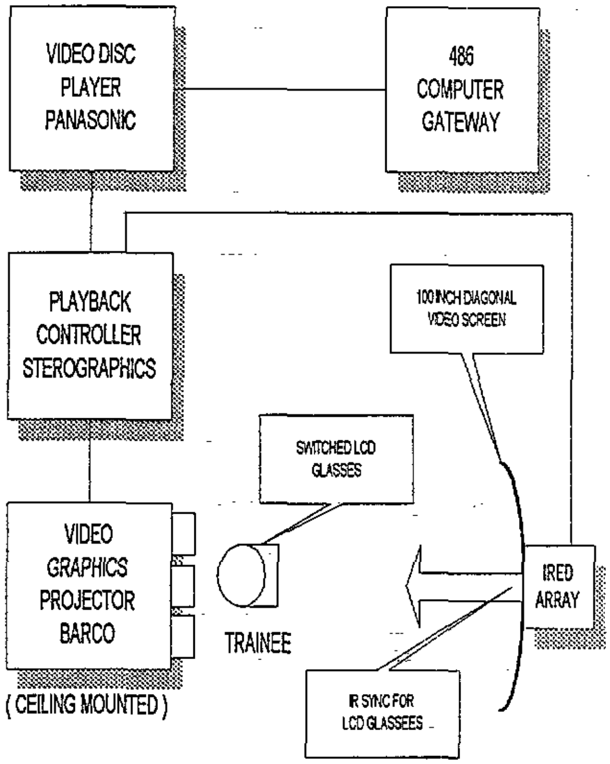


FIGURE 3. STEREO VIDEO PLAYBACK

The 120 Hz field sequential video rate is twice the customary 60 Hz field video frame rate. If alternate stereo information was recorded at alternate 60 Hz frame rate objectionable flicker would occur. However, operation at a 120 Hz frame rate requires that the glowing phosphors used in the TV projection tubes no longer emit light prior to the next field being projected. Special low persistence phosphors are used in the TV projector selected. Incomplete isolation of the right and left eye information will cause cross-talk between the shuttered eyes. Cross-talk appears to the trainee as ghosting.

Three-Dimensional computer graphics objects are also added to portray tracers in space and exploding objects flying toward the trainee. The scenario data is stored on video disk. The video projection screen displays both recorded video targets and graphics overlays using a video projector and video disk player under computer control.

Moving through the environment for a single trainee is simulated using a tread mill located in front of the projection screen. The switched LCD glasses, video recording and playback controllers are made by SteroGraphics. See Reference 1.

Each trainee has a weapon that is equipped with a collimated source of infrared (IR) energy, *an infrared emitting diode (IRED). The* collimated infrared source is aligned with the trainee's weapon and places an eye-safe infrared spot on the video projection screen corresponding to the location the trainee is pointing his weapon. Figure 4 shows the *infrared spot tracker imaging diagram.*

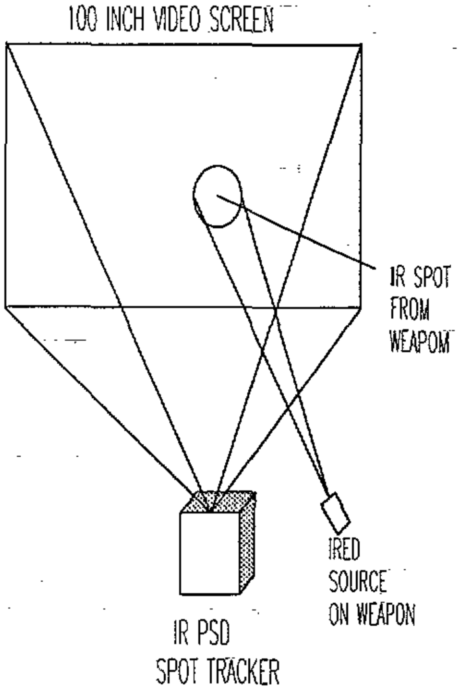


FIGURE 4. INFRARED SPOT TRACKER IMAGING DIAGRAM

The infrared sources are sequentially modulated in a time-multiplexed mode by the system computer to both identify the active weapon and to improve signal detection. A high-speed, low cost, infrared spot tracker determines the continuous X and Y position coordinates of each weapon. The optical system for the infrared spot tracker (IST) views the entire video projection screen. The infrared spot imaged onto the projection screen surface is optically transferred or reimaged to a corresponding location on a Position Sensing Detector (PSD). The system computer determines the position coordinates of the infrared spot on the PSD and consequently the video projection screen as well. The high-speed PSD-based infrared spot tracker, generates the continuous position coordinate data of each weapon in less than 3 milliseconds; in contrast, a typical CCD-based tracker would require over 16 milliseconds. See References 2 and 3.

Once the system computer knows the position coordinates of a weapon, it can compare that data to the stored coordinates of active targets on the projection screen at the time of trigger pull. If the IST position data matches the coordinates of a target on the projection screen, a kill, wound, or miss is recorded for that weapon. The ability to have targets disappear or branch after they have been hit is very important in a trainer. Trainees are encouraged to take sensible cover as they would in the real world while engaging targets displayed on the video projection screen.

Each trainee wears a modified Multiple Integrated Laser Engagement System (MILES) type torso harness containing infrared detectors and an audio alarm device to indicate if he has been killed or wounded by an on-screen aggressor. The on-screen aggressor shoot-back is simulated by using an array of infrared emitting diodes (IREDs) located adjacent to the video projection screen. Each IRED is pointed to a particular sector within the training exercise area so that all exposed areas are exposed to shoot-back by the on-screen aggressors. The individual IREDs are turned on and off by the system computer corresponding to where the on-screen aggressor is pointing his weapon when he fires at a trainee. If a trainee does not take cover while in the field-of-fire of the on-screen aggressors he will be illuminated with infrared energy.

The infrared detectors positioned on the MILES type torso vest will detect the incident IR energy and activate an alarm to indicate that the trainee has been shot by the on-screen aggressor. Once a trainee has been hit he is considered dead and his weapon is disabled. When the trainee has been killed he will hear the alarm and his weapon is automatically disabled. After a training session is over, the video scenario is played back in slow motion. The system computer shows the continuous pointing location of each weapon by graphically displaying color coded icons representing the continuous tracker position data stored by the system computer during the actual training session. Hit, wound and miss shot locations are indicated by changing the color of the icons. The instructor can see how each trainee is handling the weapon by observing the icons during play-back.

A digital sound system is used to simulate the actual acoustical training environment of each scenario. A digital sampler digitizes, stores and plays back the background sounds as well as the synchronized gun shot sounds corresponding to the trainees and the on-screen aggressors. The sampler is under the control of a Musical Instrument Digital Interface (MIDI) port interfaced to the 486 computer for the proper timing and synchronization.

The system contains a 486 computer. The computer controls the communications to the trainee and the infrared spot tracker located in front of the video projection screen. The computer also is used to control the video projector and video/graphics adapter.

A Truevision VISTA graphics board allows a programmer to manipulate the projected video display. A frame-grabbed still video image can be displayed as background. Stored video from the video disc can be displayed in several windows which can be opened or closed as the targets are hit. These windows can be opened in either a frame-grabbed or graphics background. Graphics can be displayed overlaid on live video or on a frame-grabbed or graphics background. Sections of the image, either frame-grabbed or graphics, can be moved or copied anywhere in the image; or to off-screen memory buffer for later use. Images can be saved to disk and retrieved later. A Panasonic optical disc recorder/player, is used for storage of the scenarios.

The Barcodata projector is modified with a short persistence green phosphor tube to accommodate the 3-D 120 HZ video.

Special software developed at NTSC uses the tracker data to determine miss, wound, or kill. The software, is used to mark the positions of the various potential targets in a scenario. This is necessary in order to allow the computer running the scenario to know where the friends and foes are located. This is very important for scoring hits and misses. The software allows you to step through the video scenario frame-by-frame and fit irregular polygons around the hit areas of the targets. Each hit area can represent either a wound or a kill. This information, along with the target window coordinates is stored to a file to be read back during operation of the trainer. The target window is the area on the screen where the target will appear.

The sound system provides sounds of the various weapons being fired by both the trainees and their on-screen adversaries. Background sounds are generated to increase realism during a training scenario. The heart of the sound system is a digital sampler playback module. A sampler digitizes, stores and plays back sound effects under the control of a MIDI (Musical Instrument Digital Interface) port.

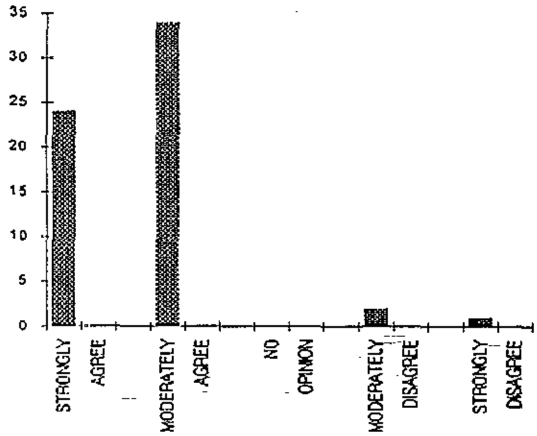
MOTION SIMULATION

Motion is currently simulated using a modified treadmill. By using the tread mill the trainee can slowly walk through the environment. A motion platform to simulate firing from a vehicle or small boat is being designed.

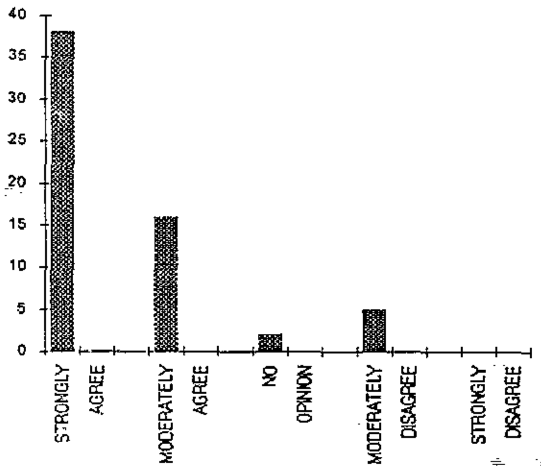
TESTING OF THE SYSTEM

The system is currently under evaluation to determine the efficacy of the 3-D prototype. The participants were asked to respond to the following statements. Initial testing evaluated 61 subjects reaction to the 3-D system. After shooting six scenarios the test subjects were asked to circle a response as strongly agree, moderately agree, no opinion, moderately disagree or strongly disagree. The results of tests are shown graphically below.

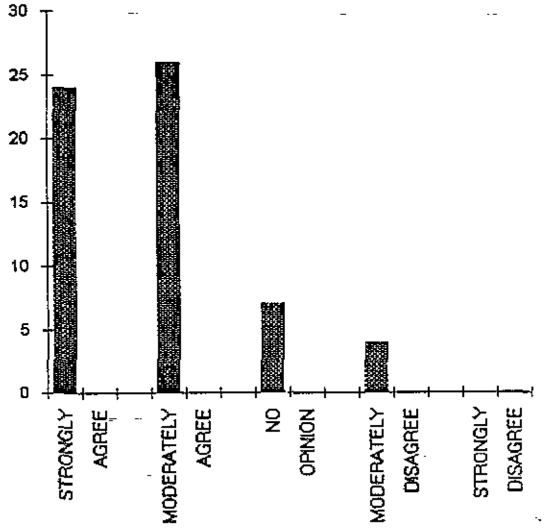
1. THE SCENARIOS APPEARED TO BE IN 3-D.



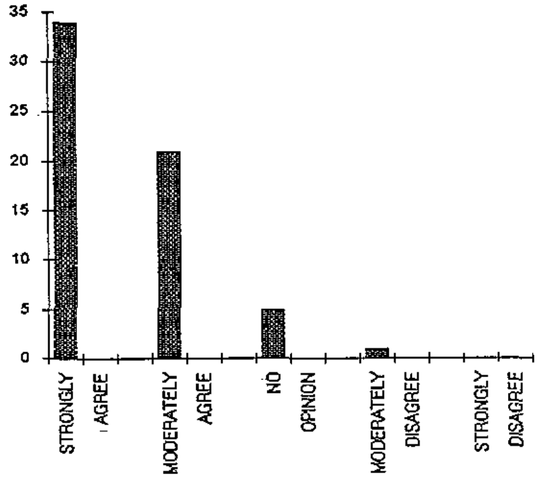
2. THE USE OF THE 3-D EFFECT MADE THE GRAPHICAL REPRESENTATIONS OF OPPONENTS MORE BELIEVABLE.



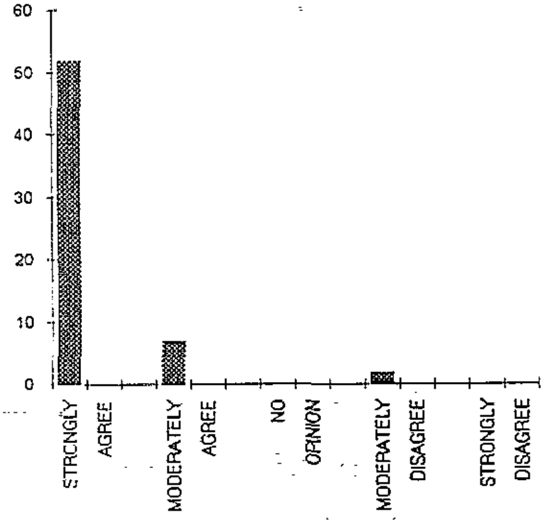
3. THE 3D GRAPHICS MADE IT EASIER FOR ME TO IGNORE MY ACTUAL SURROUNDINGS, AND THEREFORE GET MORE INVOLVED IN THE SCENARIOS.



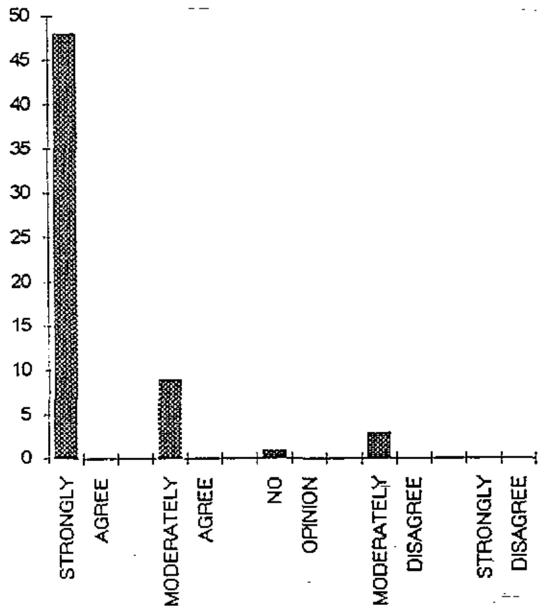
4. THE ABILITY TO GET MORE INVOLVED IN THE SCENARIOS WITHOUT DISTRACTION CONTRIBUTES TO THE TRAINING EFFECTIVENESS OF THIS TRAINER.



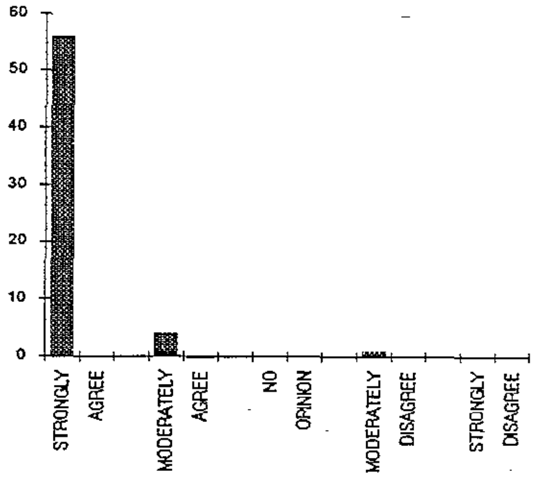
5. I DID NOT EXPERIENCE DIZZINESS DURING OR AFTER USING THIS TRAINER.



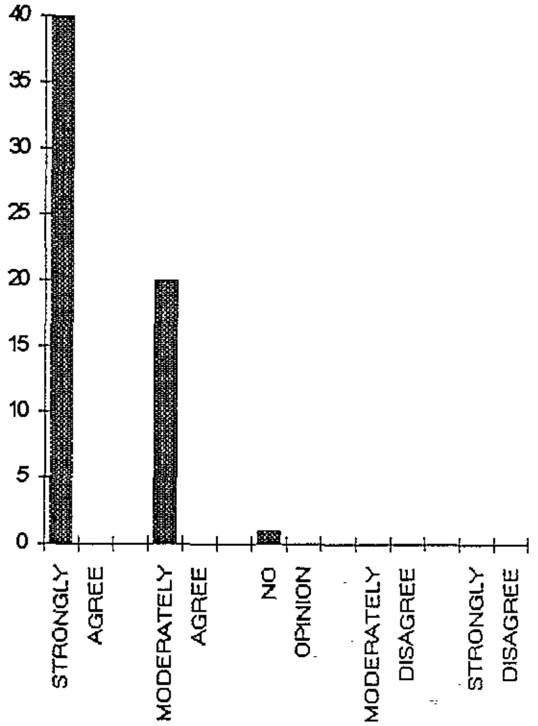
6. I DID NOT EXPERIENCE EYE STRAIN OR HEADACHE DURING OR AFTER USING THIS TRAINER.



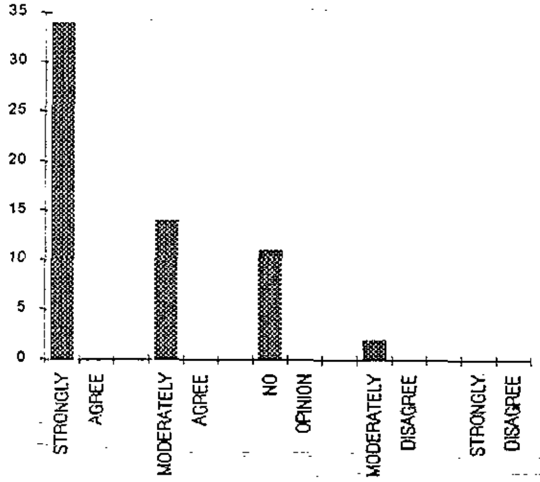
7. I DID NOT EXPERIENCE STOMACH UPSET DURING OR AFTER USING THIS TRAINER.



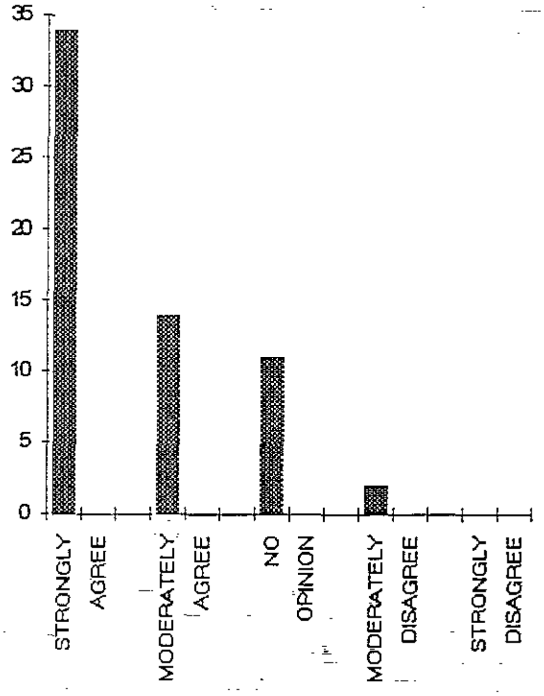
8. USING THIS TRAINER WAS AN EXCITING EXPERIENCE



9. ADDING THE 3-D CAPABILITY TO THIS TRAINER INCREASES THE COST OF IT BY APPROXIMATELY $ 10,000, I THINK THAT THE TRAINING BENEFITS MERIT THIS EXPENSE.



10. WEARING THE 3-D GLASSES DID NOT BOTHER ME OR DECREASE MY SHOOTING PERFORMANCE



RESULTS

The majority of the 61 subjects thought the addition of 3D was an exciting improvement and made it easier to ignore the actual surroundings and get more involved in the scenarios. The majority of the subjects also thought the additional cost difference over the conventional shoot-no-shoot trainer was worth it. Wearing the 3-D glasses was not deemed to bother or decrease the subjects shooting performance.

The majority of the persons that used the prototype experienced no symptoms of simulator sickness. Three of the 61 subjects had problems seeing 3-D.

CONCLUSIONS

Based upon the results of this initial testing the use of 3-D scenario presentation techniques appears to be warranted. Additional research on optimal training methods and improved 3-D display technology is continuing at NTSC. A small motion platform is currently being developed to simulate both walking and firing weapons from a moving platform..

REFERENCES

1. "The Crystal Eyes Handbook" Lenny Lipton, StereoGraphics Corp. 1991.

2. Marshall, Wolff, McCormack and Purvis. " Weapons Team Engagement Simulator", Proceedings. I/ITSC, Nov. 1990.

3. NTSC, " Weapons Team Engagement Trainer", Government Furnished Information, Dec. 1992.