Value Proposition for Augmented Reality in Synthetic Training Environments

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ABSTRACT

This whitepaper presents an overview of the advantages that Augmented Reality (AR), the combination of virtual simulation with a physical environment, can bring to Synthetic Training Environments (STEs). AR training benefits include increased retention, improved time to complete training, and better long-term performance of tasks. AR training can be quickly modified to keep pace with environments where information, technology, or personnel needs change rapidly. In many environments, it is more cost effective than traditional training, and provides an environment where high risk or physically dangerous situations can be safely enacted. Finally, studies have shown that students find AR training to be more immediate, more engaging, and less stressful, leading to an increased willingness to allocate the extra time needed to practice and achieve mastery. Realization of these benefits, however, is dependent on correctly engineered design of the training product. WisEngineering has developed strong core competency in the STE domain, from identifying the instructional elements of a training scenario that will benefit most from software simulation enhancement, to development and delivery of complete training scenarios.

ABOUT THE AUTHORS

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1. INTRODUCTION

When traditional training methods are augmented by computer simulations, training guidance, and virtual image displays, the overall retention and effectiveness of the training is measurably improved. Multiple studies confirm this (Ref [1]) in a variety of different environments, taking different types of training into account. When the student population to be trained is large, the material changes frequently, or the training involves expensive or dangerous physical elements, training simulations and computer supported training provide significant reductions in cost and risk. Contributing to both of these benefits is the appeal of an Augmented Reality (AR) training environment: studies have shown that students exhibit lower levels of "training stress" in an AR environment than a strictly physical one, they participate in the training for longer durations, with a higher percentage of students repeating exercises to achieve mastery (Ref [6], Ref [10]).

Figure 1: WisEngineering Development Lab

Crucial to the success of AR training, however, is the careful and correct design of the training, as shown in the studies below. WisEngineering, LLC (WisE) has developed domain expertise in this area and is conducting leading edge work in the Augmented Reality (AR) and Synthetic Training Environments (STE). We build tools, environments, and training packages which implement the latest research in imaging software, hardware, and concepts. We are fast becoming known for our expertise in this area: over the past 7 years we have built AR elements for several complex, immersive training systems, addressing military elements such as Paladin vehicles, Howitzer weapons, Future Vertical Lift technologies, as well AR gaming for elementary school STEM demonstrations.

This paper presents the value that AR brings to STE, and the value that WisE delivers to their customers within this domain. **Section 2** provides definitions of the terms and concepts used in this whitepaper, **Section 3** provides an overview of the benefits of AR training, and **Section 4** gives a brief summary of the key studies reviewed for this whitepaper.

2. WHAT IS AUGMENTED REALITY TRAINING?

AR is a technology that superimposes computer-generated images on a user's view of the real world, providing an amplified or "augmented" view of the environment. A heads-up computer display mounted in a jet cockpit showing computed flight data would be an example. An application in a smartphone to detect the user's location, held up to display camera images with overlaid traffic or restaurant information would be another example. That is, AR combines physical objects and virtual elements to produce an integrated environment which can move beyond the limitations of a strictly physical environment. Research has shown that enacting is better for recall than hearing the action or seeing someone else perform the action, and memory for the enacted information is better even weeks later (Nilsson, et al. Ref [5]).

AR Training is the application of AR to the needs of a student in a learning environment. A training mockup of a cockpit with a heads-up display providing instructional support along with the flight data would be an example of AR training. In an AR Training system, the student can be led through correct procedures by visual means, specific aspects of training can be highlighted, and every aspect of training can be enhanced by additional information provided directly within the training environments. When physical training and "muscle memory" are key training objectives, providing the physical environment allows the muscle memory to take place, while providing the computer augmentation can help guide the student to more accurate and successful physical repetitions. That is, the AR system works to block the incorporation of "bad habits" that can occur in unguided physical training.

WisE has developed and supported STE projects for a number of military systems, providing both physical and conceptual training. We built computer enhanced training systems and demonstrations for topics such as operating and controlling U. S. Army howitzers and soldier weapons, driving and directing U. S. Army and U. S. Marine Corps vehicles, packaging, fielding, and maintaining Department of Defense equipment of many types. The military has widely adapted AR to enhance traditional training of maneuvers and battlefield actions, medical training, vehicle operations and maintenance, weapons firing and control, and virtual bootcamps. The images below represent some of the different training systems WisE has created.

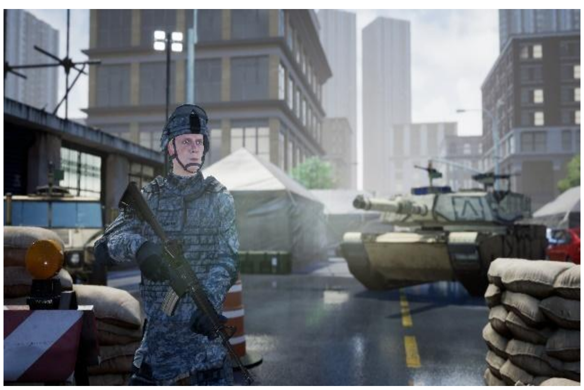

Figure 2: Mega City Training Simulation

Figure 3: Night Combat Training Simulation

3. BENEFITS OF AUGMENTED REALITY TRAINING

AR training is becoming increasingly important in all domains where information, technology, and personnel can change rapidly, or where physical training can be expensive, logistically difficult, or dangerous. While some early studies showed no significant difference between technology-based and traditionally delivered instruction, recent studies have completely reversed this thinking, providing an extensive list of the benefits delivered by an AR training environment. In domains where physical training ("muscle memory") is a key objective, numerous benefits are achieved.

Wider Scope of Training provides an environment which allows the user to engage with a greater variety of scenarios that can be offered in a strictly physical system. This means the student can be prepared for situations that only rarely occur or are expensive or dangerous to physically enact.

Safer Training Conditions: Combining simulated training elements with physical, hands-on training, results in a realistic, immersive experience in which the trainee is exposed to simulations that replicate potentially hazardous, real life scenarios with no risk of personal injury or harm to the environment.

More Effective Training: A study done by Dr. Narendra Kini, CEO at Miami Children's Health System, found that individuals retain up to 80% of information one year after virtual reality training has taken place. To put that into perspective, individuals only retain 20% of information using traditional methods of training after one year. This means that workers will learn faster and retain more information in the long term, leading to a safer and more productive work environment (Ref [9]).

Higher Engagement with Training: Active learning, increased interactivity, and a personalized, controllable simulation lead students to consistently rate their learning experience as "easier", "more fun", and allowed them to be present and more engaged with the material. This has been supported by physical testing showing increased reward response and reduced stress. (Ref [6], Ref [10]). Informed feedback is another crucial element of successful training. By integrating AR directly into the training environment, the instructor is "always on" and is always providing corrective feedback, which significantly limits error ("bad habit") propagation and allows complex concepts to be broken into manageable units. These students spend more time repeating tasks, including difficult tasks, carrying repetition to a successful conclusion.

More Cost-Effective Delivery: While the development of an AR training system represents a significant outlay of time and expense, for any situation in which the above conditions are dominant, the ongoing cost of operations will be reduced enough to make this development worthwhile. An AR system can accommodate greater numbers of students across multiple sites, without having to deploy multiple hardware assets, or require the development of customized physical environments.

4. STUDIES EVALUATING AR TRAINING RESULTS

This section presents a summary of key studies specifically applicable to the conditions this paper is focused on: training in which physical tasks are primary. There are many additional studies, however these were chosen as being most directly applicable to WisE's current work.

4.1. Increased Efficiency and Accuracy of STE Flight Training

At Arizona State University, researchers studied student pilots training in the use of a Flight Management System (FMS) on a jet aircraft (Karp, Spiker, et al, Ref [2]). The FMS is the pilot's primary interface to the software that controls the plane's navigation and performance. 14 students participated in this study, comparing STE and conventional training. Both versions of the training material were nearly identical; only the method of presentation varied.

The results showed a 17% increase in accuracy of the STE group over the control group, with a 10% reduction in time taken to complete the training. Those in the AR training group found the games to be more engaging and challenging, leading them to repeat practice and complete the training objectives at higher accuracy rates rather than those in the traditional training group.

Table 1 shows these results, noting that the difference in Time to Complete falls within the limits of standard error and may therefore be statistically equivalent.

Group	Accuracy Score (points)		Time to Complete (seconds)	
	Mean	**Standard Error**	**Mean**	**Standard Error**
Augmented (AR)	70.1	2.3	850	86
Traditional	59.7	3.8	927	108

Table 1: Results of Karp et al Aircrew Training Study

4.2. Effect of AR Training for Different Skill Levels

In a study regarding the elements required for successful AR Training (Mautone, Spiker, et al, Ref [4]), the authors ran several different, parallel training sessions comparing AR Training to conventional training. The results were clear cut: well designed, AR Training provides better training effectiveness and efficiency at all skill levels. In the case of the intermediate training, long term (delayed) retention was also evaluated.

The figures below compare traditional Computer Based Training (CBT) and AR Game Based Training (GBT). After the training phase the students were tested, and two indicators were measured: accuracy of task completion (effectiveness) and time required to complete the task (efficiency). The results are shown in the figures below.

Figure 4: Beginner Training Level 1

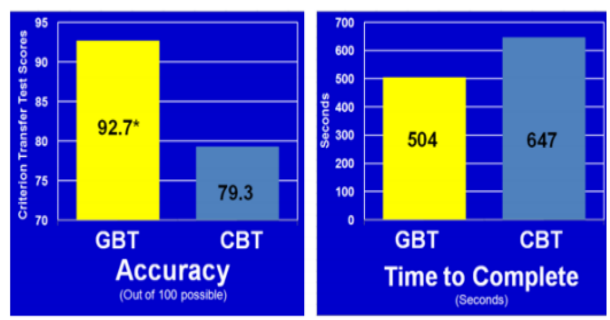

Figure 5: Advanced Training: Levels 1-6

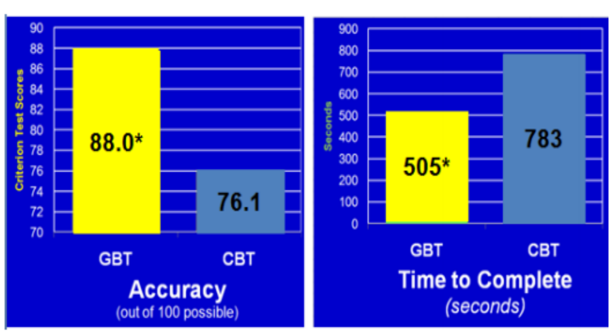

Figure 6: Intermediate Training: Levels 1-3

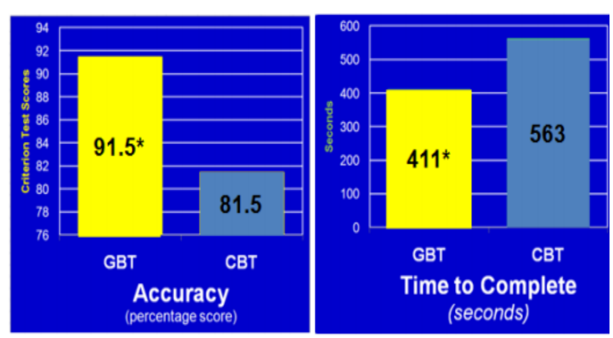

Figure 7: Intermediate Training - Delayed Retention

4.3. Effects of AR on Learning Physical Tasks

Fully immersive AR allows students to repeat difficult motions as often as needed and allows for full mobility by capturing human motion and reproducing the same motion in the virtual representation. In this study (Patel et al. Ref [6]), a comparison is made between learning tai chi in an AR setting and a traditional (not augmented or immersive) instructional video setting. The study reconstructed a three-dimensional model of participants as they moved. 26 undergraduate students participated and were split evenly into two groups by training type and by gender. Normalization was performed to remove any differences stemming from gender, age, or prior subject matter experience.

The participants learned tai chi from a prerecorded teacher model; they watched and mimicked the teacher to the best of their ability while being videotaped. They then reviewed their videotaped performance.

- In the traditional training group, participants watched a video playback of the instructor's movements. The video recording played at the same rate as during initial training, and participants were not able to control any aspect of the recording or playback.
- In the AR training group, participants physically moved, then reviewed a 3D rendering of themselves as they interacted with the virtual teacher. They were given depth cues and control over the playback conditions (e.g., angle, speed, distance).

The participants were then tested on the individual moves as the examiner verbally provided them with the name of all three moves. The participant performed the moves, one at a time, to the best of his or her ability, then filled out a questionnaire regarding engagement and usability of the environment.

Of the 26 participants, those in the AR training group consistently outperformed participants in the traditional training group. Participants reported significantly higher social presence (engagement) in the AR group than in the traditional group. Participants in the virtual settings group performed better during every phase of the experiment.

Table 2 shows the mean and standard deviation values for participants ratings in each group for all tests. In each evaluation phase the scores for the AR group have statistically significant higher values, indicating that students learned better in the AR environment from the very start.

Group	Phase 1 (point score)		Phase 3 (point score)		Testing (point score)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Augmented (AR)	2.10	0.69	2.23	0.71	2.34	0.54
Traditional	2.83	1.04	2.88	1.08	3.04	1.18

Table 2: Results of Patel et al Physical Training Study

4.4. Better and More Confident Retention

Augmented Reality displays, such as Head-Mounted Displays (HMD), provide a superior spatial awareness by leveraging our balance and motion awareness, as compared to traditional desktop displays. This study (Krokos et al., Ref [3]) found that virtual memory techniques in an AR environment provides superior memory recall ability compared to a traditional (in this case) desktop condition. The study included 40 participants, 30 male and 10 female, from University of Maryland campus and surrounding community. Each participant had normal or corrected-to-normal vision (self-reported). The study session for each participant lasted around 45 minutes. The participants were shown two scenes, on two display conditions (head-tracked AR display and a mouse-based interaction desktop), and two sets of faces. In the scoring process measured the accuracy of image recall.

- The overall average recall performance of participants in the AR group was 8.8% higher than the average recall score of desktop group.
- AR subjects reported slightly higher confidence levels in the correctness of their answers.

5. CONCLUSION

AR training is becoming increasingly important in all domains because of its numerous advantages in efficiency, cost, flexibility, and safety over more traditional training methods. WisEngineering is developing realistic, immersive STE experiences for military equipment in which the trainee is exposed to simulations that replace potentially hazardous, real life scenarios with safe simulations. The effectiveness of AR training is dependent on well-engineered selection of the simulation assets, and the end-to-end quality of the scenario implementation. We have specific domain expertise in the design and development of robust STE training packages, from analysis of team objectives, through scenario design, simulation element selection, and final training product development and delivery.

6. REFERENCES

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