AUGMENTED REALITY AS A TRAINING MEDIUM FOR AVIATION/AEROSPACE APPLICATION

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Augmented Reality (AR) has the potential to transform aviation/aerospace training by creating new mixed reality worlds that serve as a medium for gaining work related skills. AR is a mixed reality environment generated through machine vision and computer graphics technology that merges real and virtual objects in unified, spatially integrated scenes. Using AR to develop augmented scenes in a highly memorable framework can complement human information processing, and such a complement can reveal itself in training efficiency applicable to a wide variety of work related tasks. This research determined that AR-based learning affects long term memory by reducing the amount of information forgotten after a seven day intervening time between immediate recall testing and long term retention recall testing. Continuing research in the field of AR applications for training is necessary because of human variabilities, the potential for increased learning performance and significant decreases in training time.

INTRODUCTION

Augmented Reality (AR) is being adapted by practitioners to meet organizational and individual training needs (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre, 2001; Billinghurst & Kato, 2002; Vincenzi, Valimont, Macchiarella, Opalenik, Gangadharan, & Majoros, 2003; Macchiarella & Vincenzi, 2004). AR is a machine vision and computer graphics technology that merges real and virtual objects in unified, spatially integrated scenes. In AR, the surrounding environment is real and virtual elements are fused as seamlessly as possible in real time. AR scenes display three common characteristics:

- The scene combines real world environments with computer images;
- The scenes are interactive in real time;
- The scenes are registered in three dimensions (Azuma, 1997; Azuma et al., 2001).

The goal of AR is to enhance human performance and interaction with the real world through computer-generated information that is properly aligned and integrated with scenes of the real world. Applications of AR for use in real world work settings are limited by the tradeoff between processing power and portability of computers. However, these limitations are rapidly disappearing as the processing power of computers increases and size of the computer decreases.

As part of the effort to capitalize on the positive effects hypothesized for AR-based training, the authors conducted research and are developing applications of AR for aerospace industry implementation (see Figure 1). The initial development of an AR system for task training was a video-based presentation established in a laboratory environment; an AR system with this functionality served as the training apparatus for the research reported here. Ongoing and future research at the university entails developing mobile augmented reality systems (MARS) with an optical see-through presentation. Small, wearable, and powerful computers will enable AR-based training systems to create mixed reality worlds in real world work settings possible fundamentally altering worker training.

Several key factors typify the demanding training needs associated with training pilots as well as many other aviation/aerospace workers. Training and re-training of many tasks performed requires a significant amount of time and resource investment by the industry. The state of aerospace related training can be advanced using AR due to unique characteristics obtained when merging synthetic and real objects in unified, spatially integrated scenes. Potential benefits to users of AR-based training can be analyzed by reference to cognitive psychology in the areas of reduced error likelihood, recall, control of attention during training, and concurrent training and performance (Macchiarella, 2004; Neumann & Majoros, 1998; Vincenzi et al., 2003).

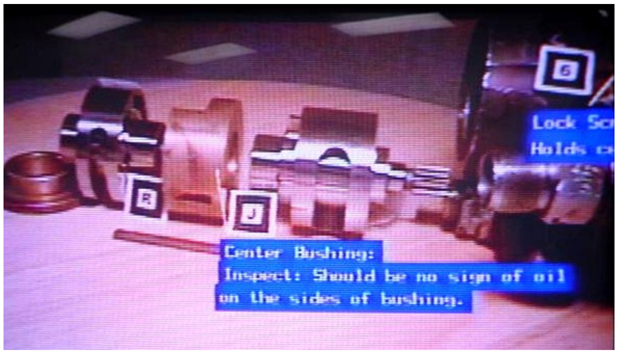

Figure 1. AR Scene used for Aircraft Maintenance Training Research

Embry-Riddle Aeronautical University (ERAU) is engaged in an ongoing effort to explore applications of AR as part of an effort to meet the aviation/aerospace industry's training needs. The authors examined how effectively AR served as a learning paradigm and then compared it against present learning paradigms, such as video-based instruction, interactive instruction, and print-based instruction.

It has been proposed that the media form presented by AR is complementary to human cognitive processes (Neumann & Majoros, 1998; Tang, Owen, Biocca, & Mou, 2003). Evidence suggests that AR has a considerable effect on recall by establishing to-be-recalled items in a highly memorable framework (Macchiarella, 2004; Neumann & Majoros, 1998). Using AR to develop augmented scenes in a highly memorable framework can complement human information processing, and such a complement can reveal itself in training efficiency applicable to a wide variety of complex domains. Based on literature relating to AR, cognitive psychology, and learning and memory, it was hypothesized that individuals participating in AR-based learning would score significantly higher on an immediate recall test, and a long-term-retention-recall test when compared to undergraduate students who participated in video-based learning, interactive augmented reality (IAR)-based learning, and print-based learning.

The authors use the term interactive augmented reality (IAR) to describe the interactive mode. IAR is derivative of AR in which the user has the locus of control regarding which aspects of the virtual world are synthesized with the real world into a spatially integrated scene. In several respects, IAR is analogous to a multimedia form of AR with hypertext like linking. Research participants were able to active and deactivate the virtual text with a hypertext-like function.

METHOD

The researchers randomly selected 96 participants for the study from the undergraduate student population at ERAU. ARToolKit v. 2.431 (Kato, Billinghurst, & Poupyrev, 2000) served as the software to render all AR scenes.

Participants studied a Power-Driven Rotary Oil Pump (see Figure 1) from a Model T53-L-13B turbine aircraft engine (Department of the Army and Air Force, 1981). The assigned maintenance task was to conduct a visual inspection of the oil pump with the purpose of being able to recall the names of the major components of the pump and several selected functionalities for the components. Participants studied the oil pump removed from the engine and in a state of disassembly. Participants were not required to assemble or disassemble the oil pump as an aspect of the study.

The experimental design consisted of a between subjects design. The between subjects variable, mode of information presentation, consisted of four levels: video-based (V) presentation, interactive augmented reality (IAR) presentation, augmented reality (AR) presentation, and print-based (P) presentation. The dependent variables for this study were immediate recall (IR) and long-term recall (LTR).

Each participant was involved with three research sessions. In session one vision and visuo-spatial ability was tested. Reading a Snellen eye chart tested participant vision. A locally produced visuo-spatial test assessed the each participant's spatial ability. In session two, participants were randomly assigned to an experimental group and given instructions on how to use the appropriate experimental materials/apparatus. Each participant received an eight-minute instructional session in order to learn about the terminology, functions, and locations of the oil pump and its components.

The experimental groups were comprised of 24 participants. Group 1 underwent video-based training, and received specific instructions on how to use the VCR and prescribed training video recording tape. Group 2 underwent IAR training. They received instruction on how to use the AR workstation in an interactive mode to bring up virtual text boxes. Upon the click of a mouse button, participants viewed superimposed virtual text on the work piece scene. Group 3 experienced video-based AR. Virtual text annotations automatically bloomed in the video scene of the oil pump as the AR workstation identified fiducials. Finally, participants in Group 4 received print-based training. This group received instructions on the nature of the text they read and pictures of the work piece for their use while studying. Immediately following the eight minute instructional session, the participants were given a three minute break to use at their discretion. When the participants returned, the researcher administered the immediate-recall test to measure how much knowledge they acquired from the instructional session and had encoded into memory. Fifteen questions were asked on the test. These tests were scored on a zero (low) through one hundred (high) scale, with 100 % correct being a perfect score.

Following the immediate-recall test, a short exit interview was conducted to debrief the participants and record their opinions on the instructional mode they experienced. The researcher provided no feedback on the participant's test performance. This concluded session two. The typical duration of session two was 45 minutes.

Session three occurred seven days after session two. Individually, participants received the long-term-retention-recall test to measure their ability to recall information encoded into long term memory about the oil pump. Participants were not provided feedback on previous performance or afforded an opportunity for rehearsal. Participant completion of the long-term retention recall test concluded session three, and all of the participants' involvement with the experimental testing. Session three typically took 15 minutes. However, participants were allowed any amount of time they deemed necessary to complete the test. Fifteen questions were asked on the test. This long-term-retention-recall test was scored on a zero (low) through one hundred (high) scale, with 100% correct being a perfect score. Completing the long-term-retention-recall test concluded session three.

RESULTS

Group means were statistically compared using a 4x2 mixed analysis of variance (ANOVA). The results of the visuo-spatial testing did not yield any significant correlation between a participant's visuo-spatial ability and their performance during the experimental recall tests. The means for the main effect of mode of presentation for the augmented reality (AR), interactive augmented reality (IAR), video-based (V), and print-based (P) modes were 10.17, 10.79, 10.69, and 9.85 respectively. These means did not differ significantly indicating that none of the different modes of presentation produced significantly better learning or recall when averages across both test conditions.

The means for the main effect of test scores between the immediate-recall test (IR) and long-term-retention-recall test (LTR) were 10.98 and 9.77, respectively. These means differ significantly, $F(1,92) = 28.99$, $p < .001$. This simply indicates that as time passed participants forgot information.

The individual cell means of each mode of presentation were compared with respect to the IR test and LTR test. The means for the AR, IAR, P, and V modes of presentation for the IR test were 10.46, 11.04, 11.00, and 11.42 respectively. The means for the AR, IAR, P, and V modes of presentation for the LTR test were 9.88, 10.54, 8.71, and 9.96 respectively. These means differ significantly, $F(3,92) = 3.522$, $p = .018$, indicating that a significant interaction between the modes of presentation and the amount of information retained over time (see Figure 2).

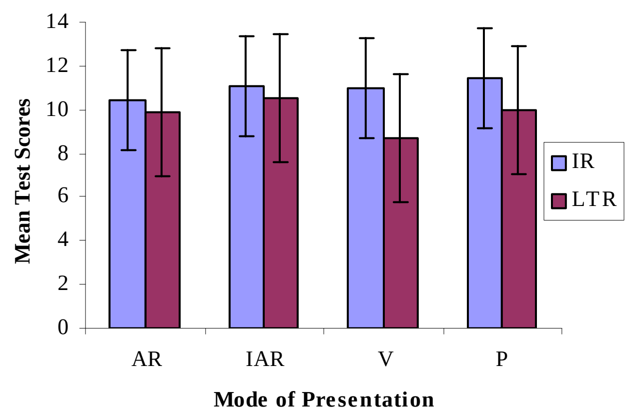

Figure 2. Test Scores for Mode of Presentation Across Both Test Conditions with Standard Deviation

Multiple paired-samples t-tests were performed on the individual cell means for the modes of presentation to determine which means differed significantly. A Bonferroni adjustment of the planned comparisons was used to adjust for the multiple t-tests, and an Alpha of .0125 was calculated.

The results of the paired samples *t*-tests indicated that no significant difference was found between the IR test and the LTR test for the AR mode or for the IAR mode. A significant difference was found between the video mode test scores, $t(23) = 2.876$, $p=.009$, and between the print mode test scores, $t(23) = 4.441$, $p < .001$. This appears to indicate that certain modes of presentation (i.e., AR and IAR) produced better learning and retention of information since the amount of information loss between the IR test and the LTR test was minimal and not statistically significant. However, the amount of information lost for the print-based and video-based modes was statistically significant between the IR test and the LTR test, indicating that the material learned while using this mode of training was not retained as well.

DISCUSSION

With regard to retention in long term memory, AR and IAR appeared to more effectively encode information into long term memory. Multiple paired-sample *t*-tests indicate memory loss during the intervening seven-day period was not significant. While the AR or IAR instructional modes did not enable significantly higher scores on the IR and LTR tests, they did demonstrate a smaller change in score between the two tests when compared to the other modes (see Figure 2). This research indicates that AR and IAR are instructional modes that lead to an increased ability to retain long term memories. This finding coincides with other researchers (Majoros & Boyle, 1997; Majoros & Neumann, 2001) who state that AR has a considerable effect on recall by establishing to-be-recalled items in a highly memorable framework.

The data did not indicate that AR and IAR participants had higher levels of recall, however, the data revealed no significant difference between scores on the IR and LTR test for AR and IAR-based learning. In essence, participants using AR and IAR forgot less of the information learned during training after an intervening seven day period of time.

This research found that AR apparently has an affect on information recall over time, but determining the full nature of the effect necessitates further investigation. Essentially, AR learners did not display higher levels of recall as evidenced by higher levels of learning (i.e., scores on the recall tests), but they forgot less of the learned information over time.

It is possible that learning paradigms using real world objects and virtual objects in unified integrated scenes (e.g., AR or IAR) do complement human associative information processing and aid information integration through multi modal sensory elaboration by utilizing visual-spatial, verbal, proprioceptive, and tactile memory while the learner is performing knowledge acquisition tasks. This belief appears as a common direction of thought with researchers and scientists in the field of AR (Macchiarella, 2004; Majoros & Neumann, 2001; Valimont, 2002).

CONCLUSION

The main conclusion from this research study is that an application of AR did not enable learners to recall more information during testing, but it did apparently enable them to recall from long term memory a greater percentage of what they had learned following an intervening seven day period.

Further research on the effect of AR on human cognitive processes is necessary to isolate human variabilities associated with learning, encoding information into long term memory, and subsequently recalling the information.

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