NEW DESKTOP VIRTUAL REALITY TECHNOLOGY IN TECHNICAL EDUCATION

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ABSTRACT

Virtual reality (VR) that immerses users in a 3D environment through use of headwear, body suits, and data gloves has demonstrated effectiveness in technical and professional education. Immersive VR is highly engaging and appealing to technically skilled young Net Generation learners. However, technical difficulty and very high costs have kept immersive VR out of most education institutions and corporate training programs. Now, a new technology is making the learning benefits and competitive advantages of VR possible cost effectively. This new technology, called desktop virtual reality, has recently improved dramatically and can now put high-quality virtual environments on standard desktop and laptop computers. This paper introduces instructional uses of VR, reviews the characteristics and benefits of desktop VR, overviews the hardware and software required to develop and use desktop VR for learning and training, and reviews the theoretical foundations and experimental findings from a research program on this innovative technology currently in progress at Oklahoma State University in the United States.

Keywords: virtual reality, technology research, instructional design, instructional theory.

INTRODUCTION

Many visual technologies have influenced and improved instruction in technical education and enhanced the preparation of workforce specialists, technicians, and professionals. Visual technologies have brought into classrooms and laboratories a realism that has improved comprehension, increased learning performance, and reduced training time. While many new technologies have become successful, the authors of this paper believe that "occasionally … there arrives a training technology that causes a realization that 'this changes everything.' Such a technology is virtual reality (VR)" (Ausburn & Ausburn, 2004, p. 33).

The term virtual reality (VR) has undergone continuous changes of definition since it was introduced in the late 1960s as immersive experiences with computer generated imagery through head-mounted displays (HMDs). The term now refers to a variety of computer-based experiences ranging from totally immersive environments with complex HMD equipment, auditory input, voice activation, data gloves, and even body suits wired with biosensors for advanced sensory input and biofeedback, to realistic PC-based imagery (Ausburn & Ausburn, 2004; Beier, 2004). However, in all its forms, VR is basically a way of simulating or replicating a three-dimensional environment and giving users a sense of "being there," taking control, and personally interacting with the environment with their own bodies (Arts and Humanities Data Services, 2002; Ausburn & Ausburn, 2004; Beier, 2004; Brown, 2001).

Immersive VR technologies have been demonstrated in a large body of published research to be very effective for teaching and learning but to be too expensive and technically difficult for most training institutions and businesses. However, there is now an alternative to the difficulty and costs of immersive VR. New desktop VR systems have recently improved dramatically in quality and realism and are now capable of bringing the benefits of VR to training institutions and businesses at a reasonable level of cost and technical requirements. As virtual reality becomes more popular and possible as an instructional option, it is important to understand the characteristics, uses, benefits, issues, and effectiveness of this emerging technology. This paper introduces VR as an instructional technology and examines its research history and the recent findings from a program of studies being conducted at Oklahoma State University in the United States.

A Comparison of Immersive and Desktop Virtual Reality

VR technologies can be broadly divided into two categories: immersive VR and desktop VR. Fully immersive VR learning systems are technically complex and very expensive computer-generated environments that have reached a very high level of sophistication. They use HMDs, body suits, computer programs, and special room-size spaces to physically surround learners in 3D worlds. One of the most common of these technologies is the Cave Automatic Virtual Environment (CAVE) system. In CAVEs, the illusion of physical immersion is created by projecting stereo images on the walls and floor of a room-size cube. Participants wearing stereo glasses enter and walk freely within the CAVE room, and a head-tracking computer continuously adjusts the stereo image projection to the current position of the viewer (Beier, 2004). CAVEs and their portable versions called ROVRs, in which stereo images are projected on a large screen and manipulated by users wearing special glasses to create the illusion of 3D, can produce remarkably realistic immersive experiences for learning (FakeSpace, 2007). Immersive augmented reality (AR) combines viewing real-world or video-based environments with superimposed 3D virtual objects that can be manipulated by learners. While these immersive VR systems are very effective, they have major financial and technical obstacles. One obstacle is their very high costs. CAVEs and ROVRs can require outlays of hundreds of thousands of dollars. They are also technically very advanced, requiring highly specialized and expensive computer programming skills to develop VR programs.

In contrast to immersive VR systems, the new desktop VR is technically far simpler and less expensive. Several differences have been described between desktop and immersive VR. Simpson (2003) described desktop VR as using conventional desktop computers and multimedia. Ausburn and Ausburn (2004) pointed out that desktop VR uses mouse or joystick navigation through a 3D environment on a graphics monitor under computer control. In desktop VR movies, learners use a mouse or other navigation device to move and explore within a virtual environment on the monitor screen, as if actually moving within a real place. This new desktop VR uses a desktop or laptop computer and special software based on QuickTime, Flash, and JAVA technologies. Desktop VR movies can be either panoramas (pans), objects, or mixed-mode scenes in which multiple pans and/or objects are combined and embedded, and then interlinked through clickable "hot spots." When operating a VR movie, the learner is in complete control of the learning experience, choosing where and when to move within the scenes, when to zoom in and out, and what "hot" objects to select, rotate, and examine.

This new desktop VR offers an alternative to expensive and technically complex immersive systems while maintaining the major characteristics that make VR highly effective for learning. Critical features of desktop VR technology for teachers and trainers, are its technical simplicity and low costs compared to immersive systems. Desktop VR can be easily distributed on the Internet or on CD, and users need little skill to install and play the VR on a standard desktop or laptop computer using a simple software viewer program. The technical skills required to create desktop VR are possible for computer-literate instructors with two or three days of in-service training. Useable desktop VR applications can be developed with an equipment investment of around $US3000 plus a high-end off-the-shelf desktop computer (a "game box" is ideal) and some software. The equipment and software required for production include a good quality digital camera, a camera tripod with a special pan head, and VR software that ranges from $US400 to about $US1200. To play back and study desktop VR programs, learners need only an ordinary current-model personal computer and a QuickTime, Flash, or JAVA player available as free downloads from the Internet.

Review of Research in Instructional VR

Reasons for VR's Instructional Effectiveness

Published research has demonstrated that VR has been successful as an instructional technology across many different subjects, perhaps because of its properties of learner immersion and interaction with the learning environment. In early VR research, Winn et al. (1997)

proposed that three factors contribute to the capabilities and impacts of VR. They are: (a) immersion, (b) interaction, and (c) engagement and motivation. Evans (1995) also supported the value of the interactivity of a VR experience, claiming that it makes learning more attuned to human experience. Selwood, Mikropoulos, and Whitelock (2000) proposed that VR's effectiveness comes from its ability to activate the intellectual, social, and emotional processes of learners. SunriseVR (2007), a VR production company, praises the technical characteristics of VR, claiming that it combines the power of a computer, the information in an encyclopedia, the imagery of a movie, and aspects of real life to create a powerful learning experience. Seth and Smith (2002) claimed that the effectiveness of VR comes from its ability to let learners experience a strong sense of presence in, and interaction with, a scene. They also attributed the success of VR to its ability to provide depth cues in stereo imagery that helps learners to understand 3D spatial relationships in a scene.

Perhaps for all these reasons and other theoretical concepts discussed below, published literature shows that VR is frequently effective as an instructional technology. Reviews of the published research show that VR has produced exciting learning results in a wide variety of different applications and support Watson's (2000) conclusion that "Most would consider that … [VR] systems provide strong potential … for the educational process" (p. 231).

Literature reviews by the authors of this paper (Ausburn & Ausburn, 2004, 2006; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007a, 2007b) have revealed several major themes that have emerged in the study of instructional VR.

Disadvantages and Limitations of Instructional VR

Several researchers have pointed out the limitations of VR as an instructional tool. One major issue discussed by Mantovani, Gaggiolo, Castelnuovo, and Riva (2003) and by Riva (2003) is the high level of skill and cost required to develop and teach with VR, particularly immersive systems. These researchers pointed out that very high levels of computer programming and graphics expertise are required to create immersive VR, and that considerable skill is also needed to use it effectively for instruction. They also mentioned health and safety concerns with VR HMDs, which have often caused headaches, nausea, balance upsets, and other physical problems. While these problems seem to have largely disappeared from current VR research as equipment and software have improved, little is known about possible long-term physical or psychological effects of VR usage. Another equipment problem comes from the fact that VR requires expensive high-end computing hardware for development and successful presentation. Riva (2003) and Sulbaran and Baker (2000) pointed out that inadequate computing equipment can seriously limit the response time for navigation and interaction in a virtual environment. This can destroy VR's sense of reality for users. This response problem is sometimes called the "latency problem" of VR. It can also be caused by bandwidth limitations when VR is distributed over a network or the Internet.

Other problems for VR are related to instructional design. Riva (2003) claimed that weak instructional design, along with the latency problems associated with technical limitations, can result in inadequate "reality" in a virtual environment. This will prevent virtual training from transferring to the real world. Studies by Wong, Ng, and Clark (2000) and Sulbaran and Baker (2000) also stressed the importance of good instructional design in VR and warned that the design must avoid overly complex navigation controls, inconsistent and unappealing look and feel, and misplaced learner attention focus.

Research Support for VR and Empirical Evidence of its Success

In published literature reviews (Ausburn & Ausburn, 2004; Mantovani, Gaggiolo, Castelnuovo, & Riva, 2003) and in the personal experience of the authors, technology researchers and technical instructors have generally agreed that VR is an exciting instructional medium and can provide a unique and highly effective way to learn when it is appropriately designed and applied. It is also agreed that VR is highly motivating to learners. In the research, several specific situations have been discussed in which VR has strong benefits and advantages. For example, VR has shown great value in situations where it would be impossible or inconvenient for learners to explore real-world environments or to interact with real objects or people, or where an environment exists only in computer-generated form (Mikropoulos, Chalkidis, Katsikis, & Kassivaki, 1997; Pantelidis, 1993, 1994). VR has also proved to be very useful when learners need to display, visualize, manipulate, and interact with information (Pantelidis, 1994; Sulbaran & Baker, 2000). Another highly beneficial use of VR is as an instructional and practice alternative when real-world experience is hazardous to learners, instructors, equipment, or the environment. This advantage of VR has been reported by developers and researchers from many fields such as firefighting, military and law enforcement, anti-terror response, nuclear decommissioning, equipment driving and safety, hazard detection, and aircraft inspection and maintenance (Government Technology, 2003; Halden Virtual Reality Center, 2004; LaPoint & Roberts, 2000; Sandia National Laboratories, 1999; Sims, Jr., 2000). Recent studies by the authors (Ausburn & Ausburn, 2006; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007b) have demonstrated that VR is effective in helping learners to orient themselves in a complex visual environment and to locate items relative to their own position.

Positive effects of VR as an instructional technology have been empirically documented in a large body of research literature across a wide variety of programs and subject areas. The medical/dental field has perhaps been most active in VR research. Riva (2003) discussed virtual environments in medical training and concluded that VR had been revolutionary and in some cases more effective than traditional training methods. Ausburn & Ausburn's (2004) review of VR literature reported numerous successful applications of VR in medical and dental training. Ausburn, Ausburn, Cooper, Kroutter, and Sammons (2007a) recently reviewed uses of new advanced VR technologies for training in laparoscopic surgery, carotid angiography, emergency medicine, and cardiology.

According to the literature, many other occupations and industries have benefited from VR and have used it to gain competitive advantage for their personnel and products. The authors have presented extensive discussions and documentations of this literature (Ausburn & Ausburn, 2004; Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007a). These discussions have reported successful uses of VR training in a wide variety of fields including airline safety for pilots, flight attendants, and ground personnel; welding; military; law enforcement and crime scene investigation; firefighting; hostage negotiation and terrorism response; emergency medical response; aviation and space exploration; marine studies; nuclear energy; hazardous materials handling; dangerous driving situations; mining; railway operations; business and economic modeling; design and prototyping of cars, submarines, heavy equipment, and aircraft; lathe operation; equipment stress testing; accident investigation and analysis; biotechnology; spray painting; equipment operation; hazard detection and prevention; and pedestrian safety.

Emphasis on Immersive VR

One more trend is apparent in the VR literature. The research focus has been on immersive and technically complex VR systems, with very little reported about the instructional effects of new desktop VR technologies. This is probably because desktop VR is newer and has only recently become good enough to be taken seriously as an instructional tool. While a few studies reported positive results for desktop VR prior to 2005 (Jeffries, Woolf, & Linde, 2003; LaPoint & Roberts, 2000; McConnas, MacKay, & Pivik, 2002; Scavuzzo & Towbin, 1997; Seth & Smith, 2002; Wong, Ng, & Clark, 2000), these are small in number and certainly inadequate to establish good empirical support for instructional uses of desktop VR. The emerging quality and potential of the new desktop VR technologies combined with a lack of research support is a serious problem for their use in instruction because it is these new PC-based systems that bring the benefits of VR within the technical and financial reach of most schools, instructors, and businesses. This situation caused a team at Oklahoma State University in the United States to focus its attention on research on the effects of desktop VR in technical education and training. The rest of this paper discusses the recent research on desktop VR and what the researchers have learnt about it.

Desktop Virtual Reality Research at Oklahoma State University

The virtual reality research team at Oklahoma State University (OSU) is currently conducting a series of studies to examine the effects of desktop VR in technical education and to develop design guidelines for this technology. The research is experimental in nature and is based on a theoretical framework that combines several concepts from the field of instructional design.

Theoretical Framework for the OSU VR Studies

Much research in instructional technology has been flawed by lack of good theoretical grounding. Many studies have been merely descriptions or "case studies" of trial uses of technology with a particular content and learner group. Without theoretical foundations, the results of these case studies cannot be accurately interpreted or generalized to other circumstances and are not useful in establishing instructional design guidelines for the technology. Therefore, the first job of the OSU research team was to establish a theoretical framework for predicting and interpreting the results of desktop VR research.

The framework for our current VR studies has combined several pieces of instructional theory. These theories have been applied within the research procedures of Cronbach and Snow's Aptitude-Treatment-Interaction (ATI) research design model. In the ATI model (Cronbach and Snow, 1977), research examines how specific learning tasks, types of learners, and instructional methods interact with each other to produce differences in learning outcomes. This type of research is generally experimental in nature and uses analysis of variance (ANOVA) statistical procedures for data analysis. Using this ATI research model, the OSU VR studies have been based on the following theories:

1. *Supplantation theory:* Supplantation can be defined as creating an instructional presentation that works with learners' abilities or does for them what they are unable to do in order to successfully complete a learning task (Ausburn & Ausburn, 2003; Salomon, 1970). In a learning task that required spatial orientation and memory for details in a complex scene, the task is made more difficult for learners when presented in a series of still images by the need to hold and manipulate in memory complex sets of visual details and relationships from image to image. However, when the task is presented with virtual reality, the mental imagery retention and manipulation requirements are supplanted by the presentation medium because it accomplishes these functions for the learner. It could therefore be predicted that VR could lead to better learning performance than a presentation based on the kinds of still images that are frequently used in textbooks and slides.

2. *Cognitive load theory:* Sweller's (1988, 1999) cognitive load theory claims that best learning occurs when learners' working memory load is kept to a minimum to facilitate changes to long-term memory. According to this theory, learning suffers when information is very difficult to process mentally, and processing load increases with the amount of information to be processed. These principles suggest that VR would benefit learning by combining the visual details from many different still images into a single visual field, which would reduce the cognitive load of having to do this mentally. The VR medium would, in fact, supplant this mental process by letting the technology perform to this function for learners.

3. *Dale's Cone of Experience:* This well known instructional design theory says that more concrete and realistic types of experiences and media facilitate learning, particularly when reality is complex and unfamiliar to learners (Dale, 1954). One of the major characteristics of VR is the accuracy and completeness of its presentation of the reality of a 3D environment and the spatial relationships of items within it. It could therefore be predicted that VR might help learners experience a 3D environment more realistically than a set of still images and result in better learning performance.

4. *Communication theory and channel noise:* Shannon and Weaver introduced the concept of channel noise in

their classic model of the communication process, which has historically been considered a key development in information theory (Shannon, 1948; Weaver & Shannon, 1949), particularly in technology communications. According to this theory, an intended message traveling through a channel or medium between a sender and a receiver can suffer from interference due to "channel noise" caused by an overload of information. Because VR creates a very complex visual field, it is possible that this channel noise could actually increase the cognitive load for learners and might work against the benefits of supplantation and concreteness. This might result in poorer learning performance with VR than with still images.

5. Self-efficacy theory: In his theory of self-efficacy, Bandura (1997) defines self-efficacy as a person's belief in his or her ability to successfully perform a certain task. Because VR may have characteristics of supplantation, concreteness, and reduction of cognitive load, it might be predicted to increase the technology self-efficacy of learners and therefore increase their feelings of confidence and mastery as well as their actual learning performances.

6. Theories of individual learner differences: Learners have many differences in age, gender, experiences, and learning styles. Many instructional technology studies have found important differences in the ways various media interact with and affect the performance of different kinds of learners. Because this research history suggested that learners with different characteristics would be affected differently by VR, learner variables were built into the OSU studies as part of the ATI research design.

Based on these theories, the OSU VR team has recently conducted a series of studies of the effects of desktop VR. The research procedures and results of these studies are reported in the following sections.

Research Procedures for OSU VR Studies

The OSU studies of desktop VR have been quasi-experimental in design. They have focused on applications of desktop VR in technical education and have had convenience samples of technical and occupational students and educators as participating subjects. All the OSU studies have used random assignment of subjects to treatment groups and post-test-only research designs. All data have been collected in technical education institutions by trained members of the VR research team using standardized protocols to ensure uniform data collection procedures. The sample sizes have been small, and the studies have been considered to be pilot studies that will point the way to larger studies in the future.

Description and Findings of the OSU VR Studies

Table 1 summarizes the principal findings, data sources, and general statistical results of the five OSU VR studies. Methodological and statistical details are provided in-text for each study.

Study #1:Desktop VR versus Still Images in Presenting a Non-Technical Scene:

The purpose of this study (Ausburn & Ausburn, 2006) was to compare the effectiveness of desktop VR with traditional still color images in presenting a non-technical scenic environment to learners of various ages and gender. This study applied established instructional design principles to a new technology (VR) with unknown characteristics and compared it to a graphic medium (still images) that is currently extensively used for instruction in technical education. The study addressed three aspects of learning outcome by comparing scores of learners who received a desktop VR presentation of the interior rooms of a house with the scores of learners who received still images of the same scene. The house interior was chosen because it was not technically intimidating to learners, could not have been previously seen by any subject, and yet represented the requirement to understand location of items in a scene which is common in technical education. The subjects were 80 adults drawn from the general population. The 80 subjects were stratified by gender and age as follows: 20 males aged 18-35, 20 males aged 36-60, 20 females aged 18-35, and 20 females aged 36-60. Equal numbers of subjects from each gender and age group were randomly assigned to

Study Topic and Principal Findings	N	Statistical Test of Significance	Statistical Results
#1 *Desktop VR vs. Still Images in Presenting a Non-Technical Environment to Different Genders and Age Groups*	N=80		
Scenic orientation better with VR for both genders and younger/older age groups		2-way ANOVA	*statistically significant with moderate effect size
Recall of details better with VR for both genders and younger/older age groups		2-way ANOVA	*statistically significant with moderate effect size
Learner confidence higher with VR for both genders and age groups		2-way ANOVA	*statistically significant with moderate effect size
Females had better scenic orientation and recall of details than males		2-way ANOVA	*statistically significant with moderate effect size
Younger group more confident than older group		2-way ANOVA	Trend
Both the gender and age groups are more confident with VR, but not to same extent		2-way ANOVA	Trend
#2 *Desktop VR vs. Still Images in Surgical Operating Room Training with High-Visual and Low-Visual Learners*	N=31		
On 1 complex learning task, LVs did better with still images,While HVs did better with VR		2-way ANOVA	**Statistically significant with large effect size
LVs more confident with still images, but HVs more Confident with VR		2-way ANOVA	**Statistically significant with large effect size
Lvs found task more difficult than HVs		2-way ANOVA	**Statistically significant with large effect size
LVs found task more difficult with VR, but Hvs found task easier with VR		2-way ANOVA	**Statistically significant with large effect size
Issues with VR found under experimental conditions disappeared in typical classroom usage			Qualitative Data from students and teachers
#3 *Comparison of Effects of Desktop VR with and without Guided Navigation*	N=42		
Navigation aids may effect VR viewing time more than learning performance		2-way ANOVA and t-tests	Data still under analysis
Gender effects may be important in performance and confidence with VR in technical environments			
#4 *Using Priming Techniques to Influence Perceptions of* Educators about VR	N=30		
Positive priming increased VR viewing time over negative or no primes		1-way ANOVA	Trend with large effect size
Positive priming increased confidence with VR		1-way ANOVA	*Statistically significant with large effect size
Positive correlation between VR viewing time and confidence		Correlation	*Statistically significant
#5 *Desktop VR and Individual with Disabilities*			
Several new technologies allow desktop VR to be Accessed by people with some physical disabilities	Review of existing technology tools		

* Statistical significance set at *p* .05

** Statistical significance set at *p* .10

Table 1. Summary of Findings of Desktop VR Studies at Oklahoma State University

receive either VR or still imagery presentation. The VR presentation was a panorama movie with hot spots for navigation; the still image treatment was eight color photographs containing identical information and shot with the same camera as the VR movie. Both presentations were presented on a personal computer under learner control, and both contained identical instructions to the subjects for completing the research task. All subjects received brief training on how to operate the learning program they would be using. After receiving their instructional presentations, subjects completed three testing instruments developed by the research team to measure various aspects of learning performance. The first test was a measure of scenic orientation. This was 15 multiple choice items that required subjects to position or locate themselves mentally within the house scene and identify the location of designated objects in relation to their position (such as "behind you" or "to your left"). The performance measure was number of correct responses out of 15. The second measure was recall of scenic details. This was defined as the number of correct and non-duplicative items, excluding large pieces of furniture, in the house scene that the subjects could recall and list within a time of one minute. The third measure was perceived confidence level in scenic comprehension. This was measured by the subjects' self-reported confidence in their understanding of the details of the scene on a 5-point scale from '*1 = no confidence*' to '*5 = absolute confidence*'.

All data collected were coded and entered into the SPSS computer program for statistical analysis. Analyses included descriptive statistics and 2-way analyses of variance (ANOVAs). Two sets of ANOVAs were performed: One set for gender by instructional treatment on each of the three performance variables, and one set for age by treatment on each of the performance variables. Statistical significance level for the ANOVAs was set at p = .05; effect size was measured by the eta-squared (^{2}) statistic. On the scenic orientation variable, the VR presentation resulted in superior learning performance of moderate effect size for both gender (F = 5.51; df = 1,79; p = .02; ^{2} = .11) and age (F = 4.92; df = 1,79; p = .03; ^{2} = .06). VR treatment also produced superior performance of moderate effect size on recall of details for both gender (F = 6.95; df = 1,79; p = .01; ^{2} = .08) and age (F = 6.31; df = 1,79; p = .01; ^{2} = .08). Learner confidence was also higher with VR treatment with moderate effect size for both gender (F = 8.54; df = 1,79; p = .005; ^{2} = .10) and age (F = 8.73; df = 1,79; p = .004; ^{2} = .10). These data allowed the conclusion that overall, the VR presentation produced better scenic orientation, recall of details, and learner confidence than the still image presentation.

Several other findings of this study were interesting. Overall, the females performed significantly better than the males with moderate effect size on both scenic orientation (F = 9.62; df = 1,79; p = .003; ^{2} = .11) and recall of details (F = 7.78; df = 1,79; p = .007; ^{2} = .09). On the confidence variable, the younger group was more confident at a level that approached statistical significance (p = .09). Interactions on learner confidence for both gender by treatment (p = .09) and age by treatment (p = .06) also came close to statistical significance. In these interactions, both gender and age groups reported greater confidence benefits with the VR treatment, but not to the same extent. In the gender interaction, the females benefited more in confidence from VR than the males; in the age interaction, the younger group had the greatest confidence benefits from VR. Other interactions that showed trends below the level of statistical significance indicated that the females and the younger learners benefited more than the males and the older learners from VR on their scenic orientation scores.

Based on the theoretical predictions for this study, the findings of superior learner performance and confidence with VR were expected. The study appeared to support the possibility that desktop VR may have beneficial properties of supplantation, concreteness, cognitive load reduction, and self-efficacy. The findings of greater confidence overall by the younger learners and greater gains by this group in both confidence and scenic orientation performance with VR were also as expected. These result appear to support the well-documented technology skills and self-efficacy of the young Net Generation (Howe & Strauss, 2001; Tapscott, 1998). In contrast, the findings of superior performance of females overall in scenic orientation and recall of details were unexpected based on a long history of stronger skills in mental spatial manipulation by males in both paper-andpencil and virtual environments (Space, 2001; University of Washington, 2001). An explanation for these unexpected gender findings may be suggested in the fact that greater gains in both spatial orientation and self-confidence were made by females than males in the VR presentation. Perhaps the greater supplantation benefits were felt by the group with the greater need for it. This possibility merits further investigation in future VR research.

The findings of this study guided the OSU VR research team to undertake a second study that used similar procedures to examine the effects of desktop VR in a specific technical setting with learners who that had different visual learning styles.

Study #2: Comparing Desktop VR with Still Images in Surgical Operating Room Training with Learning with Different Learning Styles:

The purpose of this study (Ausburn, Ausburn, Cooper, Kroutter, & Sammons, 2007b) was to compare the effectiveness of desktop VR with traditional still color images in presenting an operating room environment to surgical technology students with high and low levels of visual perception skills. In this study, six aspects of learning outcomes were the dependent variables: (a) accuracy of scenic orientation, (b) recall of scenic details, (c) perceived confidence in scenic comprehension, (d) perceived difficulty of the learning experience, (e) time on learning task, and (f) time on test of scenic orientation. This study used very similar research procedures as Study #1. This time, the subjects were 31 young adult Licensed Practical Nursing students in a large urban technical education center who had not previously seen the training operating rooms shown in the instructional presentations. Instead of gender and age, the learner variable in this study was perceptual type, as defined by Lowenfeld (Lowenfeld & Brittain, 1987). In Lowenfeld's theory, “visuals” are learners who are skilled in discriminating visual details and in forming, manipulating, and retaining mental imagery; “haptics” do not have these skills and prefer to trust their tactile and physical feeling senses.

To determine their visual or haptic perception styles, the 31 subjects in this study took a new video version (Study, 2001) of Lowenfeld's old original film version of Successive Perception Test 1 (SPT1) that was identical to the original version. In SPT1, subjects view a series of 35 abstract patterns a small section at a time behind a moving slot. They then see five similar variations from which they must select the one that exactly matches the pattern they saw behind the moving slot. Based on their SPT1 scores, the subjects were separated into 3 groups: High Visuals (HVs; highest 1/3 of the scores), Indefinites (middle 1/3), and Low Visuals (LVs; bottom 1/3). The middle group was eliminated from the study, which left 9 HVs and 9 LVs who were randomly assigned to receive either a desktop VR or a still image presentation of a pair of surgical technology operating rooms (ORs). This study was conducted much like Study 1. Also, the performance variables of scenic orientation, recall of details, and perceived confidence were measured much as they were in the previous study. Also measured were, the subjects' feeling of how difficult the learning activities were (on a 5-point scale), the time they took (up to 10 minutes) to study their VR or still image presentation, and the time they took to complete the multiple choice test of scenic orientation. The VR movie and the still color images contained identical information. Both presentations contained labels identifying various equipment and items in the ORs. In the VR presentation, numerous clickable “hot spots” were available to allow the learners to jump from one OR to the other and to explore various items and views within each OR.

All obtained data were entered into the SPSS computer program and then analyzed with descriptive statistics and 2-way ANOVAs. A significant level of $p = .10$ was selected for this study because of its small sample size and highly exploratory nature; effect size was measured with the eta-squared (^{2}) statistic. A p-level of .20 was accepted as indicating a trend that might merit further investigation, particularly when effect sizes were large. As a follow-up to the experiment, the VR presentation was given to a team of two surgical technology instructors. They were asked to use the presentation in any way they chose for instruction with their new students who had not participated in the experiment and to record their comment and ideas and those of their students about the VR presentation of the OR scenes. These comments were later collected and analyzed to compare results of classroom instructional use of the VR with the findings of the controlled experiment.

Several interesting findings emerged in this study. On the part of the multiple choice test of scenic orientation that required comparing the details of the ORs simultaneously, there was a statistically significant interaction with a large effect size between perceptual type (HV or LV) and presentation method (F = 5.82; df = 1,17; p = .03; ^{2} = .29). This interaction was disordinal, meaning that the results were different for the two perceptual types. The LVs did better with the still image presentation than with the VR presentation, but the HVs did better with the VR presentation. This may mean that on this complex visual integration task, the LVs were more troubled by the channel overload and increased cognitive processing load in the VR presentation, which caused them to lose the value of the supplantation and concreteness that benefited the HVs. There were also some significant results with large effect sizes on the learning task perception variables. On the perceived confidence score, the still image presentation produced better confidence results overall than the VR presentation (F = 3.56; df = 1,17; p = .08; ^{2} = .20). There was also a disordinal interaction between perceptual type and presentation method (F = 7.14; df = 1,17; p = .02; ^{2} = .33). Examination of this interaction showed that the superiority of the still image treatment came entirely from the LVs, who felt less confident with VR than with still images. However, the HVs actually felt more confident with VR than with still images. This finding seemed to support the idea that the LVs were more affected by the information and cognitive processing overload in VR than by the supplantation and concreteness benefits of VR. Significant results with large effect sizes were also found for the ratings of the learning task difficulty. Overall, the LVs thought the learning task was more difficult than the HVs (F = 3.24; df = 1,17; p = .09; ^{2} = .19). They also felt that the task was more difficult with VR than with still images, while the HVs found the task easier with VR (F = 3.83; df = 1,17; p = .07; ^{2} = .22). Once again, this seems to support the idea of greater negative effects of VR visual overload and loss of supplantation-concreteness benefits by the LVs.

The findings of this experiment clearly suggested that the visual complexity of VR clearly had different effects on LV and HV learners. It had a negative impact on learners with low visual processing skills. For these learners, the problem of visual load in VR counter-acted the benefits of supplantation and concreteness. In contrast, for learners with high visual processing skills, the benefits of VR had a positive effect that was more important than its visual load.

This data picture changed somewhat when the surgical technology instructors and students used the VR presentation in a classroom situation instead of a controlled experimental one. Two important findings came from the open comments about the VR when it was used in an uncontrolled teaching setting. First, there were not any negative comments about VR; no concerns were expressed about its visual complexity or its navigation problems. Second, the instructors and students produced nine different ideas for additions to the VR operating room scenes, including attaching videos showing "how to" skills, adding more item labels, and adding pop-up text boxes with more information. All these suggestions would add both visual and navigational complexity to the VR scenes. Concerns about information overload from a complex visual field and navigational interface were not at all evident in these comments. It therefore appeared that when the VR presentation was moved out of a controlled research setting and into a classroom instructional setting where instructors and students could take as much time as they wished to learn to operate the VR and to explore its contents; issues of overload may have disappeared and the supplantation-concreteness benefits of VR may have become more important.

Overall, this study's findings suggested that sufficient time to practice operating and exploring VR is important, and may be especially important for learners with low skills in processing visual information. The study also suggested that the researchers should look for techniques that might increase the beneficial supplantation characteristics of VR (such as providing learning time and navigational guidance) and decrease the negative information overload characteristics (such as controlled disclosure of details). This idea led to the next experiment in this research series.

Study #3: Comparing Desktop VR with and without Guided Navigation.

This study is currently being conducted by the OSU VR research team with 42 surgical technology students. Its purpose is to see if learning performance and confidence are improved by adding navigation assistance to desktop VR. This study is very similar to study #2, expect that instead of comparing VR to still image presentation of surgical technology operating rooms, the comparison is between VR presentations with and without on-screen navigation guidance. Findings from this study should be available in Spring, 2008. Preliminary analyses suggest that navigation assistance may produce longer VR viewing time but not necessarily subsequent learning performance, and that gender effects may be important in performance and confidence with VR in a technical environment.

Study #4: Influencing the Perceptions of Educators about Desktop VR.

A study by Williams (2007) examined a different aspect of VR. The purpose of this research was to see if the opinions of technical educators about desktop VR could be influenced, with the idea that if a more positive attitude could be created, then faster adoption of this technology might happen. Based on priming theory (Bargh, Burrowns, & Chen, 1996; Claypool & DeCoster, 2004), Williams used positive and negative stimuli in the form of jumbled sentences containing pleasant and unpleasant words to "prime" technical educators before showing them a desktop VR presentation. A group of 30 educators were randomly assigned to receive positive, negative, or no prime and then were asked to view the VR program. This study found that the educators who received the positive prime tended to view the VR presentation longer (F = 2.695; df = 2, 27; p = .09; ^{2} = .17) and felt significantly more confident on a five-point scale (F = 4.061; df = 2,27; p = .03; ^{2} = .23; Tukey NSD on the 2 primed groups = .7000; p = .02) that they could describe the scene to another person than either the no-prime or the negative-prime group. There was also a statistically significant correlation between viewing time and confidence (r = .85; p = .000. r^{2} = .72). These findings have important implications for desktop VR research. They suggest that it may be possible to use priming, and possibly other methods, to help to speed up the adoption of VR by technical instructors. If research continues to demonstrate that this new technology is an effective tool for teaching and learning, then an understanding of ways to increase the disposition of instructors and administrators to use it could be very valuable.

Study #5: Desktop Virtual Reality and Individuals with Disabilities.

If desktop VR is a valuable tool for teaching and learning, it is important to know if it can be used by people with disabilities. The purpose of this study by Dotterer (2007) was to discover if current technology exists that allows desktop VR to be used by individuals with disabilities. The study located, discussed, and demonstrated several new "assistive technologies" that allow desktop VR to be played and studied by people with visual, hearing, and mobility problems. The new technologies discovered include text captioning, audio narration, and verbal interaction between user and computer, which can now all be attached to desktop VR programs to make them more accessible to people with disabilities.

Conclusion

This paper has introduced virtual reality technology, particularly the new and recently improved desktop VR. It has presented relevant research, discussed theoretical foundations for studying and understanding the effects of VR, and reviewed recent VR research being undertaken by the VR research team at Oklahoma State University. Desktop VR has recently improved technically and can now offer instructors an excellent tool at reasonable levels of cost and technical skill. This technology can motivate learners and enable them to explore and understand many environments that are inconvenient, costly, or dangerous to visit in the real world. It can offer schools, universities, and businesses a training tool that appeals to the young, technology-literate generation and gives a competitive advantage in attracting students and employees. While research on this new desktop technology is just beginning, the early findings are encouraging. Desktop VR is a promising new technology that merits serious consideration and continued research.

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References

[1]. Arts and Humanities Data Services. (2002). Creating and using virtual reality: A guide for the arts and humanities. Available at http://wads.ah.ds.ac.uk/guides/vr_guide.

[2]. **Ausburn, F. B., Ausburn, L.J., Cooper, J., Kroutter, P., & Sammons, G. (2007a).** Virtual reality technology: current status, applications, and directions for education research. OATE Journal: Oklahoma Association of Teacher Educators, 11, 7-14.

[3]. **Ausuburn, L.J., & Ausburn, F.B. (2003).** A comparison of simultaneous vs. sequential presentation of images in a visual location task: A study of supplantational instructional design. OATE Journal: Oklahoma Association of Teacher Educators, 7, 1-20.

[4]. **Ausburn, L. J., & Ausburn, F. B. (2004).** Desktop virtual reality: A powerful new technology for teaching and research in industrial teacher education. Journal of Industrial Teacher Education, 41(4), 33-58.

[5]. **Ausburn, L. J., & Ausburn, F. B. (2006, December).** Effects of desktop virtual reality on learner performance and confidence in environmental mastery: Opening a line of inquiry. Paper presented at the National Research and Professional Development Conference, Association of Career and technical Education Research, Atlanta, GA, USA.

[6]. **Ausburn, L. J., Ausburn, F. B., Cooper, J., Kroutter, P., & Sammons, G. (2007b, December).** Virtual reality in surgical technology education: A study in instructional theory and design. Paper presented at the National Research and Professional Development Conference, Association of Career and Technical Education Research, Las Vegas, NV, USA.

[7]. **Bandura, A. (1997).** Self-efficacy: The exercise of control. New York: Freeman.

[8]. **Bargh, J., Burrows, L., & Chen, M. (1996).** Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. Journal of Personality and Social Psychology, 71(2), 230-244.

[9]. **Beier, K. P. (2004).** Virtual reality: A short introduction. Available at http://www-vrl.umich.edu/intro/index. html.

[10]. **Brown, R. D. (2001).** Welcome to the world of virtual reality. Available at http://www.crd.rea.ac.uk/staff/richard/vr.html.

[11]. **Claypool, H., & DeCoster, J. (2004).** A meta-analysis of priming effects on impression formation supporting a general model of informational biases. Personality and Social Psychology Review, 8(1), 2-27.

[12]. **Cronbach, L. J., & Snow, R. E. (1977).** Aptitudes and instructional methods: A handbook for research on interactions. New York: Irvington.

[13]. **Dale, E. (1954).** Audio-visual methods in teaching (Rev. ed.). New York: The Dryden Press.

[14]. **Dotterer, G. P. (2007, December).** Desktop virtual reality and individuals with disabilities: Status of the technology. Paper presented at the National Research and Professional Development Conference, Association of Career and Technical Education Research, Las Vegas, NV, USA.

[15]. **Evans, C. (1995, June).** WWW-VRML benefits. Available from http://www.thinkofit.com/webconf/icde95/0038. htm.

[16]. Fakespace. (2007). Products. Available at http://www.fake space.com.

[17]. Government Technology. (2003). News release: NIST developing virtual reality training tools for firefighters. Available at http://www.govtech.net/news.

[18]. Halden Virtual Reality Center. (2004). Information,

products, and projects. Available athttp://www.www2.hrp.no/vr.

[19]. **Howe, N., & Strauss, W. (2001).** Millenials rising: The next great generation. New York: Vintage Books.

[20]. **Jeffries, P. R., Woolf, S., & Linde, B. (2003).** Technology-based vs. traditional instruction: A comparison of two methods for teaching the skill of performing a 12-lead ECG. Nursing Education Perspectives, 24(2), 70-74.

[21]. **LaPoint, J. F., & Roberts, J. (2000).** Using VR for efficient training of forestry machine operators. Education and Information Technologies, 5(4), 237-250.

[22]. **Lowenfeld, V., & Brittain, W. L. (1987).** Creative and mental growth (8th ed.). New York: Macmillan.

[23]. **Mantovani, F., Gaggiolo, A., Castelnuovo, G., & Riva, G. (2003).** Virtual reality training for health-care professionals. CyberPsychology and Behavior, 6(4), 389-395.

[24]. **McConnas, J., Mackay, M., & Pivik, J. (2002).** Effectiveness of virtual reality for teaching pedestrian safety. CyberPsychology and Behavior, 5(3), 185-190.

[25]. **Mikropoulos, T. A., Chalkidis, A., Katsikis, A., & Kassivaki, P. (1997).** Virtual realities in environmental eduction: The project LAKE. Education and Information Technologies, 2(2), 131-142.

[26]. **Pantelidis, V. S. (1993).** Virtual reality in the classroom. Educational Technology, 23, 23-27.

[27].**Pantelidis, V. S. (1994).** Suggestions on when to use and when not us use virtual reality in education. East Carolina University, VR and Education Lab.

[28]. **Riva, G. (2003).** Applications of virtual environments in medicine. Methods of Information in Medicine, 42, 524-534.

[29]. **Salomon, G. (1970).** What does it do to Johnny? A cognitive-functionalistic view of research on media. Viewpoints: Bulletin of the School of Education, Indiana University, 46(5), 33-62.

[30]. **Sandia National Laboratories. (1999).** Virtual reality training tool pits emergency rescue teams against computerized terrorist attacks. Available at http://www.sandia.gov/media/NewsRel.

[31]. **Scavuzzo, J., & Towbin, G. (1997).** Amoco's PC-based virtual reality simulation enables it to cut driver training costs. Information Systems Analyzer Case Studies, 36(3), 2-7.

[32]. **Selwood, I., Mikropoulos, T., & Whitelock, D. (2000).** Guest editorial. Education and Information Technologies, 5(4), 233-236.

[33]. **Seth, A., & Smith, S. S. (2002).** PC-based virtual reality for CAD model viewing. Journal of Technology Studies, 30(4), 32-37.

[34]. **Shannon, C. E. (1948).** A mathematical theory of communication. Bell Systems Technical Journal, 27, 379-423 and 623-656.

[35]. **Simpson, R. L. (2003).** Welcome to the virtual classroom: How technology is transforming nursing education in the 21st century. Nursing Administration Quarterly, 27(1), 83-86.

[36]. **Space, S. (2001).** Gender gap shows cyberspace bias. TRN: Latest technology research news. Available at http://www.trnmag.com/Stories.

[37]. **Study, N.E. (2001).** The effectiveness of using the Successive Perception Test I to measure Visual-Haptic tendencies in engineering students. Unpublished doctoral dissertation, Purdue University, West Lafayette, IN.

[38]. **Sulbaran, T., & Baker, N. D. (2000, October).** Enhancing engineering education through distributed virtual reality. Paper presented at 30th ASEE/IEEE Frontiers in Education Conference. Available at http://64,233,167,104/search? q=cache:ogblvlqN-ZKJ:fie.engrng.pitt.edu/fie2000/ papers.

[39]. **SunriseVR. (2007).** Welcome to learning in virtual reality. Available at http://www.sunrisevr.com.

[40]. **Sweller, J. (1988).** Cognitive load during problem solving: Effects on learning. Cognitive Science, 12, 257-285.

[41]. **Sweller, J. (1999).** Instructional design in technical areas. Camberwell, Victoria, Australia: Australian Council for Educational Research.

[42]. **Tapscott, D. (1998).** Growing up digital: The rise of the

net generation. New York: McGraw-Hill.

[43]. University of Washinton. (2001). Lost in virtual space: Gender differences are magnified. Available at http://www.washington.edu/newsroom/news/2001 archive.

[44]. **Watson, D. (2000).** Editorial. Education and Information Technologies, 5(4), 231-232.

[45]. **Weaver, W., & Shannon, C. E. (1949).** The mathematical theory of communication. Urbana, IL: University of Illinois Press.

[46]. **Williams, M. S. (2007).** Pilot study of the effects of supraliminal bipolar primes on occupational educators' viewing time and perceived confidence with desktop virtual reality. Paper presented at the National Research and Professional Development Conference, Association of Career and Technical Education Research, Las Vegas, NV, USA.

[47]. **Winn, W., Hoffman, H., Hollander, A., Osberg, K., Rose, H., & Char, P. (1997, March).** The effects of student construction of virtual environments in the performance of high - and low-ability students. Paper presented at the meeting of the American Educational Research Association, Chicago, IL, USA.

[48]. **Wong, B. L. W., Ng, B. P., & Clark, S. A. (2000).** Assessing the effectiveness of animation and virtual reality in teaching operative dentistry. Journal of Dentistry: Educational Technology Section. Available at http://www1.elsevier.com/homepages/sab/identity/contents/wong2/wong2.html.

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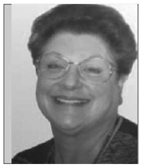

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