AFRL-HE-AZ-TR-2007-0001

Exploring the relationship between distributed training, integrated learning environments, and immersive training environments

Adrienne Y. Lee

New Mexico State University
Department of Psychology
New Mexico State University
PO Box 30001, MS 3452
Las Cruces, NM 88003

January 2007
Final Report for June 2004 to February 2006

Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Readiness Research Division

NOTICES

AFRL-HE-AZ-TR-2007-01 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//Signed//
DULCINEA E. YABUT, 2D LT, USAF
Lab Contract Monitor
Air Force Research Laboratory

//Signed//
HERBERT H. BELL
Technical Advisor

//Signed//
DANIEL R. WALKER, Colonel, USAF
Chief, Warfighter Readiness Research Division
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
18 Feb 06

2. REPORT TYPE
Final report

3. DATES COVERED *(From - To)*
30 Jun 04 – 18 Feb 06

4. TITLE AND SUBTITLE
Exploring the relationship between distributed training, integrated learning environments, and immersive training environments

5a. CONTRACT NUMBER
FA8650-04-1-6529

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Adrienne Y. Lee

5d. PROJECT NUMBER
1123

5e. TASK NUMBER
AS

5f. WORK UNIT NUMBER
1123AS07

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Adrienne Y. Lee
Department of Psychology
New Mexico State University
PO Box 30001, MS 3452
Las Cruces, NM 88003

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Readiness Research Division
6030 South Kent Street
Mesa AZ 85212-6061

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL; AFRL/HEA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-HE-AZ-TR-2007 - 01

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

13. SUPPLEMENTARY NOTES
Published as it was submitted from the author.

14. ABSTRACT
The original goal of this paper was to review the literature on the new areas of integrated learning environments and immersive training environments, as well as distance and team training and intelligent tutoring systems research, and evaluate the feasibility of integrating these ideas.

15. SUBJECT TERMS Current literature; distance and team training; distributed training; distributed training literature; immersive distributed training; immersive training; immersive training environments; integrated learning environments; proficiencies and deficiencies; tutoring systems; HBCU

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Dr. Adrienne Y. Lee
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UNLIMITED	33	**19b. TELEPHONE NUMBER** *(include area code)*

This page intentionally left blank.

Table of Contents

Exploring the relationship between distributed training, integrated learning environments, and immersive training environments

Introduction

The original goal of this paper was to review the literature on the new areas of integrated learning environments and immersive training environments, as well as distance and team training and intelligent tutoring systems research, and evaluate the feasibility of integrating these ideas.

Background

With the military's increased reliance on advanced technology, the push to acquire and maintain proficiency on the use of that technology has increased as well (Barry & Runyan, 1995). In order to maintain its preeminence, the Air Force needs to maintain an ability to use advanced training technology and deliver instruction on demand (Sikes, Cherry, Durall, Hargrove, & Tingman, 1996). New technologies are creating novel instructional methods and techniques as part of the design, such as e-learning, immersive training environments, and interactive learning environments. However, different views of how effective integrated learning environments and immersive training environments are, especially in comparison to traditional technologically-based training methods, is not well known.

While research is necessary to ultimately determine effectiveness, integration, and scalability of the technologies, thoroughly studying what exists in the literature and relating those findings to previous, earlier attempts to apply training technology can allow for more effective focusing of research efforts and avoid duplication of results. The following short sections briefly review the major areas and provide a brief background for the summaries of new research directions discussed in this paper.

1. Intelligent tutoring systems, Distributed/Distance Training, Team Training

Intelligent tutoring systems. Instruction can take many forms such as classroom lecture, group activities, and discovery learning; however, the access to technology expands the possibilities and provides a potential for individualized instruction. The basic outline for this type of individualized instruction with computers, intelligent tutoring systems, has been around since 1973 (Hartley & Sleeman, 1973); however, a real break through came when validated psychological theories about learning were applied to the creation of these systems (for summaries see Anderson, Corbett, Koedinger, & Pelletier, 1995; Corbett, Koedinger & Anderson, 1997). Although a variety of tutoring systems were proposed and some developed (Sleeman & Brown, 1982; Wenger, 1987), those systems developed by Anderson and colleagues have been used in public schools and have also continued to inform learning theory (Anderson & Gluck, 2001; Corbett et al., 1997; Koedinger, Anderson, Hadley & Mark, 1997). These tutoring systems are thus unique because they were able to scale up to a real world situation where many such systems did not.

A majority of individual tutoring systems are not scalable due to development costs, even though, unlike off-the-shelf educational software (edutainment), they provide empirical validation of learning. However, these tutoring systems have applicability in distributed/distance training situations, where trainees are expected to do some or all of their learning on their own and away from the class.

Distributed/Distance training. In recent years, the advancement of military technology has resulted in highly complex skills that need to be acquired and maintained to use that technology (Barry & Ryan, 1995). Consequently, the demand for ongoing innovations including distance training has increased. While sending personnel to training sites can be costly, recent surveys have found that considerable cost savings with comparable training outcomes can be acquired through the use of distance-learning. For example, the Asynchronous Computer Conferencing (ACC) used by the Army resulted in comparable performance between resident and ACC students but cost less (Hahn, 1990). However, even though distance learning in some form has been available for many years (e.g., correspondence courses), studies focusing on the internet/web-based training have only recently been performed and relatively few have examined the effectiveness of the technology for knowledge acquisition (Boling, & Robinson, 1999; Kerka, 1996). With increasing use of these technologies, research focused on the factors that could improve learning from this type of training would be beneficial.

While research in intelligent tutoring systems focused on the individual, issues in distance training apply equally to individuals and teams. For example, under ideal training situations, multiple individuals can be trained together to form effective teams. However, the constraints of distance and time often play a role in limiting team training. Furthermore, limitations in available personnel and the need to spread these personnel over wide geographic areas also impedes the ability to train effective teams. One solution to these problems is distance team learning.

Team/Group training. A parallel development to distance training has occurred in the area of team training. Teams play an increasingly large role in many aspects of military work. In particular, the growing complexity of tasks frequently surpasses the cognitive capabilities of individuals and thus, necessitates a team approach (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Salas, Cannon-Bowers, Church-Payne, & Smith-Jentsch, 1998). However, most individuals have little formal training in how to work within a group, much less how to learn within one. Moreover, the move toward distributed mission training for many military training programs creates new challenges for collaborative learning by teams. Trainers are faced with the problem of both training the skills directly needed for the job and the interpersonal skills needed for successful team performance. In addition, trainers and trainees must adapt to distributed training programs. At the heart of both individual and team training, however, is the ability to accurately and reliably assess learning and measure the knowledge that results from training. Although progress has been made on knowledge measurement at the individual level, the measurement of team knowledge, and team cognition in general, is still in its infancy (Cooke et al., 2000). In addition, extensive research has been performed on individual's cognitive skill acquisition (see above), however, team learning and computer supported cooperative learning have only recently become the focus of attention, especially for groups larger than two individuals. A greater understanding of what an individual learns within collaborative learning situations and, as opposed to or in conjunction with, what the team learns is needed in order to provide information for trainers.

Distance learning may have a different meaning in the context of group (collaborative) or team training. Few studies have examined collaborative (group) distance learning and even fewer studies examine team distance training (Frost & Fukami, 1997; Kerka, 1996). Computer internet/web environments have tended to be built for the individual (Calvani, Sorzio, & Varisco, 1997); however, groupware and CMC has allowed for the possibility of the delivery of team distance learning. Results from studies comparing CMC to face-to-face have found mixed results. For example studies have suggested that CMC can reduce social norms (Sproull & Kiesler, 1986), can be a hindrance to the creation of meaning (Mantovani, 1996) and can lead to lengthy decision making (Hedlund, Ilgen, & Hollenbeck, 1998) in comparison to face-to-face communication. These studies are limited because they tend to focus on organizational and social factors rather than team process, cognition and performance. Also, military teams tend to be populated by hierarchical teams of individuals each with his or her own role, as opposed to homogeneous groups of individuals making the same judgments or decisions. Therefore, in order to study team distance learning, new techniques need to be developed.

2. New ideas in training: Integrated learning environments and Immersive training environments

With the advent of more powerful computing, training systems can provide more personalized and interactive feedback to a trainee. Integrated learning environments and immersive training environments are two of the most recent approaches that leverage off of computing power for improving training.

Immersive training environments have been characterized as virtual reality technology but also include a simulation component (Furness, Winn, & Yu, 1997). Simulations and virtual reality have been used extensively for training in the military (see Tobias & Fletcher, 2000). The difference between non-immersive versions of these technologies and immersive versions can be defined in terms of the degrees of sensory impact on the trainee. Because 3D non-immersive environments can provide very realistic situations for the trainee, determining when to use the more expensive immersive technologies becomes a question. Therefore, reviewing the effectiveness of non-immersive and immersive technologies can be the first step before determining the relationship between immersive training environments and integrated learning environments.

Integrated learning environments are characterized by a systems approach and provide delivery of training on demand (often from the internet), providing alternative learning methods, and easily allow instructor management (e.g., changes of materials, monitoring students, providing correction) (Honebein, 1996; Nishinosono, 1992). This idea is a natural extension of e-learning or web-based instruction. With advancement in technology and technological proficiency of instructors, the suggestion of integrating various learning environments not only makes sense but also becomes feasible. Thus, integrated learning environments would allow an instructor to provide a variety of digital instructional media (e.g., journal articles, chat rooms, tutoring systems), while also allowing instructors to monitor and maintain contact with students. However, many tools for the internet are not integrated. Tools have been independently developed and instructors who would like to conduct their classes fully or partially via e-learning may find difficulty in reaching the goal of integration. Therefore, the time is right for additional research into deciding which tools are critical for successful integrated learning environments, the development of tools that could be integrated, usability issues involving these tools, and whether learning is improved when instructors adapt these environments. In addition, because the shortcomings in evaluations of large-scale military training simulations have been identified, it would be useful to find ways to tie integrated learning environments with current large-scale military training simulation (Simpson, 1999a, b).

Immersive training environments utilize new technology to provide a more sensory approach to learning, whereas integrated learning environments utilize combinations of tools and new takes on the learning experience. Relating results from the previously well tested area of intelligent tutoring systems and the literatures of distance and team training will provide additional insights as to how these two areas can practically and conceptually be combined and evaluated.

3. Overall summary of the technical issues

In summary, traditional research in training technology has focused on the individual. These systems have had successes and provide information about scalability and empirical evaluations of effectiveness (training validity). In addition, this research may inform distance training, but will need degrees of modification to be generalized to team training. Immersive training environments, on the other hand, extend simulation technology and provide the trainee with additional contextually-based learning experiences. All of these techniques, tutoring systems, distance and team training issues, and immersive training environments, can apply ideas derived from integrated learning environments and may do so to various extents. Reviewing these literatures to discover proficiencies and deficiencies in application will provide information about how integrated learning environments can be achieved, as well as how immersive training environments should be designed and evaluated.

Method

We focused exclusively on published empirical studies. We also included book chapters which are unrefereed. Due to the fact that there were so few published papers, we expanded slightly to include some papers from very recent conferences. The vast majority of the articles in the newest topics of distance training, team training, and virtual learning environments are opinion pieces. They also tend to focus only on a single one of these topics and therefore do not necessarily speak to the combination.

The other source for information is the internet. On the internet, you can often find information about projects on the topics covered in this paper that are being performed in academics, industry, and the military. Some of these authors have published papers that are accessible; many of these papers are conference proceedings. However, the vast majority of the sites are just descriptions of research being performed. Some information from these sources may be included where conference papers are available or citations are at least made. Although APA provides for citing from the web, web sources are often unreliable or unverifiable. So, although we used the internet to try to locate additional sources, websites are not generally included below.

Findings

General

Within the literature, virtual learning environment or virtual environment for learning can be synonymous with immersive training environment. In order to be complete, though, the terms virtual reality, simulation/immersive simulation, and training (learning, tutoring systems or training systems) should also be included. By virtual environment, though, computer scientists are generally referring to something more than a simulation. They are referring to an underlying simulation with an interactive environment and the sense for the user that he/she is <u>immersed</u> and physically interacting. The tactile (as well as audio) feedback seems to be a critical factor.[1]

---

[1] In the field of education, virtual reality environments can be broken down into 3 categories: text-based virtual environment, desktop virtual reality, and immersive virtual environments. Text-based virtual environments are like MUDs (Multi-User Dungeon or Domain or Dimension) and MOOs (MUD object oriented); and, desktop virtual reality is like simulation or synthetic training environments. Both of these lack the sensory experience of an immersive environment.

The literature consists mostly of opinion papers, technical papers (e.g., how to create virtual reality or virtual learning environments) and survey studies (e.g., what people like when they use the system.

The reason these areas are covered more than evaluative research is that even though research has been conducted in one form or another since the 1980s, it is still a relatively young field, tied to advances in technology. For example, to study teams, it is not clear that all the necessary equipment for a true tactile virtual experience is available. Head gear to eye track is still cumbersome and it still requires experts to create the programs to deal with the hardware involved.

Due to the accelerated program schedules required today, institutions (both military and non-military) adapt rather than publish (Whitworth, 2005). Therefore, evaluative research is needed in all areas, not just in cutting edge areas like virtual learning environments.

However, it is difficult to create good studies. Most labs control too many variables which makes them less ecologically valid and hard to transfer outside of the lab. If only a few variables are controlled, then it is hard to publish because traditional psychologists (or even cognitive scientists) may view the study as too uncontrolled. If a study is performed in the field, then so many variables are uncontrolled that often no real conclusions can be drawn.

What do we know?

Simulations

Computer simulations are used in just about every field to re-create some phenomenon; however, since it is based upon the programmer's conceptualization of the phenomenon and the technology available, the better the technology and conceptualization, the better the simulation. Although simulations can be used for testing equipment, a primary use has been for educating and training (O'Keefe IV & McIntyre III, 2006). Topics vary widely from standard educational topics such as teaching kids physics, mechanics, and weather (Gould, 1995; Mayer, 2003), to practical topics such as flight simulation (Gopher, Weil, & Baraket, 1994), nursing (Hamilton, 2005), business (Marriott, 2004; Valenzuela, 2003), biomechanics (Schwameder & Muller, 2001), chemistry structures (Danielsson, Banushkina, Nutt & Meuwly, 2006), and urban low intensity conflict environments (LIC; Kiperman, E., Sirkis, A., & Popovich, 2005). Virtual learning environments are dependent upon the "goodness" of the underlying simulation – the people doing the conceptualization of the phenomenon such as psychologists, scientists, mathematicians, and programmers, the technology, and the programmer's abilities.

Teams

Group learning and collaboration have been studied in social psychology and education. The connection between this field and technology started with computer supported cooperative work (CSCW; Olson & Olson, 1991). The idea in CSCW, though, was not for learning but improving people's ability to work together. Computer supported cooperative learning (CSCL) grew out of CSCW (Resta, 1995) but is mainly focused in an educational setting. Groupware is part of CSCW (Ellis, Gibbs & Rein, 1991; Kline & McGrath, 1999). Although originally designed to aid groups, and clearly could be extended to cover CSCL, research to validate has not been extensive (see Kline & McGrath, 1999.) However, researchers in the recent team literature prefer the term team over group because a team has a shared mission whereas a group may not have any reason to be together (Paris, Salas, & Cannon-Bowers, 2000). (Note that as in much of the literature, everything is compartmentalized. People, researchers and others, rarely talk across the lines of the groups that have been formed. There may be relevant research within groupware but that's somewhat beyond the scope of this paper.) The rise in team research in the cognitive science area has paralleled a decrease in group studies in social psychology (Druckman, 2004; researchers such as Mooreland are still studying these issues, though.)

Although team research could be linked to collaboration research (Levine & Moorleand, 1990), recent research has emerged from the intersection of cognitive science and human-computer interaction (for review see Paris et al., 2000; Salas, Bowers & Cannon-Bowers, 1995). The research has focused on improving methods for measuring and improving team performance (Cooke, 2005; Cooke et al., 2000; Driskoll & Salas, 1991; Dwyer, Oser, Salas, & Fowlkes, 1999; Winfred, A., Edwards, B., Bell, S.T., Villado, A., & Bennett, W., 2005; Wright & Kaber, 2005). Various factors can affect team performance such as the usability of the system (i.e., interface, how intimidating, how realistic, etc.), how evenly the work is distributed, whether the individuals have high cognitive ability, and the structure of the team itself (Ellis, Hollenbeck, Ilgen, Porter, & West, 2003; Lee, Bond, Scarbrough, Gillan, & Cooke, 2006; see also, Salas, Cannon-bowers, & Johnston, 1997; Stata, 1989). Many ways have been found to improve team performance (coordination training, leadership training, self-correction, for review see Cannon-Bowers & Salas, 1998). One example is cross-training (Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; McCann, Baranski, Thompson & Pigeau, 2000; Volpe, Cannon-Bowers, Salas, & Spector, 1995). However, as with virtual environments, systematic evaluation of systems needs to be performed more often (Salas, Burke, Bowers, & Wilson, 2001).

Cognitive variables must be combined with the social variables. Because team learning is also a social endeavor, knowledge gained by one member can pass to other members (Gruenfeld, Martorana, & Fan, 2000; Strasser, 1992). Thus, not only does training in skills such as how to communicate with other team members help but also the analysis would be incomplete without examining cultural cognition variables (such as individualism/collectivism or agreeableness (Lee et al., 2006). Team training does appear to work but factors outside of improved technology may be involved.

Simulations have been used not just for team training but also for merely measuring team behaviors; however, virtual reality environments are still quite new. For example, students can learn how to fly an unmanned air vehicle (Cooke & Shope, 2004). The US DoD has funded the Phoenix project which allows teams of engineers to design together using a simulation (Ng, Guleyupoglu, Segaria, Malone, Woyak, & Salow, 2003; see also website such as Malone, 2006 and Lee et al., 2006) where teams can use a peacekeeping simulation of Bosnia (software by Aptima Corporation). As good as these simulations are, however, they do not approach actual virtual learning environments where the team would be completely immersed in the technology (see further discussion below). Work in this area is proceeding but not yet appearing in the published journal literature. (For one recent study combining teams and virtual reality but not distance, see virtual reality section.)

Distance

The military has made a commitment to distance learning with the latest computer technology (e-learning). In a review of the factors affecting distance on-line learning, Thurston & Earnhardt (2003) note that completion rates for such courses is not as high as traditional courses and the factors affecting completion may include outside distractions, distractions in the course itself (hardware/software problems), personal commitment to the course (goals), and timely feedback on performance. The difference between personal learning and required learning is that the individual in a personal learning situation may not feel obligated to complete. However, if a team of individuals is being trained together, social pressure may create another level of obligations that helps individuals to complete training. In some cases, team distance training can be as good as or even better than team co-located training (Lee et al., 2006). Essentially, co-located training and testing may cause distractions, especially with highly complex technology or environments. The problem is that one cannot just take existing software and expect it to work in a distributed/distance fashion – either for individuals or for teams (MacDonald, 2005). Two recent studies are described next.

1. In a study performed by Beranek & Martz (2005), teams of students were asked to work together over the internet in order to improve communication. (No learning evaluations were performed.) Teams receiving training on how to interact effectively performed better on qualitative measures. This study shows how confusing the nomenclature is. In this sense, the virtual team was virtual because they were separated by a distance and the environment was virtual because it wasn't in one physical location; however, it was not a virtual learning environment in the sense that team members did not perform tasks together represented in a fully immersive, simulated environment.

2. In a study by Dornheim (2000), a distributed mission was arranged between 8 pilots using a high-fidelity F-15C simulators. Although performance was not evaluated, pilots comments were studied. The issues that arose were that simulators need to be more realistic, and developers need to reduce the system delay. In addition, budget restrictions prevent the development of full-scale implementations.

Virtual reality/Virtual environments

Virtual environments and interactivity have been the focus of attention for several decades now (Conn, Lanier, Minsky, Fisher, & Druin, 1989; Macredie, Taylor, Yu & Keeble, 1996). While the focus by developers will always be a bit skewed toward technology, recent developments have also considered the importance of human interaction (Card, Moran & Newell, 1998; see also Middleton, McIntyre III, & O'Keefe IV, 1993). This is fortuitous because virtual reality requires more than a faithful simulation but also an ability for a human to be part of the whole system.

Research: Durlach et al. (2000) presents a review of virtual environments; however, the citations mainly fall in conference proceedings and technical reports. While this would be a good initial read for an introduction to the topic, Stanney's 2002 book provides quite a bit more solid empirical data within the chapters.

Although more papers focus on commentary or technical descriptions, some papers did provide empirical evaluation of one type or another. This section summarizes relevant papers by topic.

1. Virtual humans:
People will respond to virtual humans in a more realistic way when those virtual humans respond to them more realistically (Garau, Slater, Pertaub & Razzaque, 2005). The sense is that the technology still has a ways to go before people will respond to virtual humans in the same way but this may change as people have more experience with immersive environments.

2. Fine motor skills:
Arnold, Farrell, Pettifer, & West (2002); The beginning of this paper reviews research on gross motor skills, with the general findings that people can learn but do not necessarily perform better than with real world tasks. The task involved movement of an object through a physical space, as opposed to merely picking up and grasping. In three experiments, the VE was more difficult than the real world task. In the discussion, the authors compare their work with previous studies, notably Kozak, Hancock, Arthur & Chrysler (1993) who have found less difficulty with VE. The main finding is that VE is different from the real world and therefore in order to fully test a system different tasks of varying types must be used to evaluate.

3. Building a database of results:
Loughran (1998) presents an idea and the first steps toward creating a virtual training repository. They collected about 12 months of data from the army's program and found that was difficult. The process of archiving was time consuming, error prone, and required constant oversight. Thus, although this seems like a fantastic idea, especially so that future researchers can analyze performance data, the system still has a long way to go.

4. Evaluation instruments:
The easiest and most often used measure of learning in all tutoring and training systems is the questionnaire. The most basic asks participants how they view the system (how effective is it, do you use it, and the like). For example, Ellaway, Dewhurst & McLeod (2004) present a longitudinal study of a very detailed instrument presented to medical students. This type of instrument is useful but does not really measure learning. A second type of questionnaire asks participants to answer questions directly on both the facts and ideas presented or to describe the actual procedures learned. This type of declarative test is getting closer to evaluating what the learner has obtained from the content of the training system. A third type of test involves asking the person to perform the procedures taught. These last two types (employed extensively by developers of intelligent tutoring systems) target the actual knowledge learned and carry much more value than mere questionnaires. Taken together, using all three types of instruments is the most ideal situation. A system that is used and appealing and effective in training the target knowledge is best.

In Dobson et al. (2001), the researchers describe a system where individuals can train with simulated team members. The system includes a way to capture who is interacting with whom and thereby show whether the learner is interacting with the correct individuals so that they will eventually perform well as a team. Thus, tools to improve analysis of user actions (or communications) may be useful, as well.[2]

5. Problems with technology:
a) A longitudinal evaluation of a virtual environment conducted by Tromp, Steed & Wilson (2003) found that the network technology was not good enough to provide continuous feed and that generally people found the limitations of the technology caused frustration (p.257). This study did not examine training and learning, and therefore illustrates how far technology needs to advance before training and learning issues can become the primary focus.

---

[2] Recent research on automatic team communication has shown promise for Latent Semantic Analysis (Foltz, Laham, & Derr, 2003; Foltz & Martin, 2004; Foltz, Martin, Abdelali, Rosenstein & Oberbreckling, 2006). The system has done well in predicting overall team performance through analysis of the (oral) team communication collected.

b) Linebarger, Janneck & Kessler (2004). This study focused on groups using virtual reality (not immersed) to perform a design task. Essentially issues with software and hardware were the major obstacles in task performance.
c) Park & Kenyon (1999): This study measured human performance when latency and jitter in networks was varied. Previous exposure to the task helped but performance was ultimately affected by network conditions. Long latencies and large amounts of jitter had their greatest impact on performance during difficult hand guidance tasks.

6. Transfer[3]:
a) Regian (1997) performed an experiment that consisted of two conditions: virtual environment and a simulation. The virtual reality environment was not immersive. Results indicated that participants in both conditions were able to transfer to real world tasks; however, because the system was not complex, it is hard to know whether these results would scale.
b) Witmer, Bailey & Knerr (1996): A virtual environment for a building was compared with verbal rehearsal with a computer model. Transfer to an actual building was better for those who trained in a virtual environment (faster time).
c) Tate, Sibert, & King (1997): A virtual environment training for firefighters was compared with non-virtual environment training; slight advantages during test (actually locating fires in actual shipboard locations) were found for participants in VR training.
d) Seymour, Gallagher, Roman, O'Brien, & Bansai (2002): [Note that other studies in medicine are discussed in the Medicine and Education section.] Sixteen residents were randomly assigned to a virtual reality training or standard training group. There were no initial differences in beginning knowledge but virtual reality training participants were faster at performing procedures and made fewer errors.

7. Therapy:
a) North, North & Coble (2002): This research summarizes case studies used to document therapists' use of virtual reality to treat patients. Virtual environments provide patients with a way to experience events in a simulated world. Because the environment is realistic and the individuals are immersed in those environments, virtual environments provide safe places to work on various mental illnesses. Note that these are case studies and not empirical data.

---

[3] This report is focused on published studies because they provide more back validation than studies presented at conferences. One transfer study not included: Hall, Stiles, & Horwitz (1998) presented a study comparing individuals learning in an immersed virtual reality versus a 2D environment. The VR group showed initial benefits but after 2 weeks both groups' performance was about the same. In addition, the VR group experienced nausea and other physical symptoms during initial learning. No followup or published studies were found by us (but could exist). Therefore it wasn't included officially in the list.

b) See section following on Medicine & Education; Satava & Jones (2002) also provide a review of medical applications in virtual environments.

8. General evidence of the effectiveness of virtual environments for learning has been found by several researchers:
a) Regian & Shebilske (1992): They developed a virtual reality maze. Participants were able to be trained very quickly and perform the tests very quickly. Unfortunately, the authors did not test to see whether virtual training would transfer to actual maze use.
b) Slater, Sadagic, Usoh, & Schroeder (2000): These researchers ran teams of 3 individuals in a virtual reality to measure group interactions. The task was solving a puzzle. They did not measure either learning or performance improvement. Only one participant could see his own figure in the space. (This seems to be a drawback of the virtual environment. Ideally, we'd want to be examining a virtual environment for team training where all team members are not only represented but also immersed.)
c) Swan, Gabbard, Hix, Schulman & Kim (2003): The researchers compared different interface versions of the same underlying virtual environment. Differences between the four interfaces were found. These results imply that the user-interface to a virtual environment is also an important factor for performance.
d) Witmer & Sadowski (1998): Participants were asked to use a virtual reality system or walk in real life and with either feedback or no feedback. Results indicated that distance judgments after using the virtual reality system was short compared to real life training.
e) Heldal, Steed, Spante, & Schroeder (2005): An exploratory study was performed where 6 pairs of participants were asked to use a virtual environment. Each member of a pair was in a different location. They were just asked to interact; they were not asked to learn anything in particular or any task in particular. The researchers were merely observing behaviors.

9. Leadership:Steed, Slater, Sadagic, Bullock & Tromp (1999): This study investigated how a small group of three strangers would interact when brought together in a virtual environment to perform a task. In the first experiment, ten teams were studied; but, only one person was immersed in the environment. Results suggested that the immersed person tended to emerge as a leader in the virtual group, but not in the real meeting. In the second experiment, 4 groups of three participants were studied and no participants were immersed. No special patterns of results were found. Thus, the question of how virtual learning environments promote leadership is still open.

10. Negative side effects:a) Harm (2002): The first part of the article reviews physical problems such as motion sickness and lists many citations for previous research. As many as 30% of VR users experience such severe motion sickness symptoms that they stop use. As many as 95% of VR users experience symptoms severe enough to interfere with training in the VR system. One can administer medication to overcome

side effects. Other methods include biofeedback, acupressure, acustimulation, and adaptation techniques.

Cobb, Nichols, Ramey, & Wilson (1999): Nine individual experiments were performed. Demonstration of sickness was found in all studies and across all measures. Although symptoms were often mild and short lived, in some cases, the symptoms were so severe that participants had to withdraw.

b) Lawson, Graeber, Mead & Muth (2002). This is a second chapter in the same handbook that deals with symptoms of virtual reality use. Adverse signs and symptoms are experienced by at least 10% and sometimes as many as 90% of simulator trainees. The effects include eye strain, fatigue, drowsiness, sweating, headache, and difficulty concentrating. Approximately 40% of simulator pilots have reported no symptoms, and 25% have reported only mild symptoms. However, about 5% of participants had such severe symptoms that they had to stop testing until the symptoms subsided. Testing performed on civilians showed that at least 60% of VE users will report adverse symptoms during their first exposure.

c) Viirre & Bush (2002): This is the third chapter in the same handbook that deals with symptoms of virtual reality use. The symptoms identified by the authors are eye strain, seizures, migraines, noise levels, skin irritation, and physical injury.

d) Regan (1997): A high incidence of self-report symptoms (such as nausea) was measured (61%) and possible causes discussed.

e) DiZio & Lockner (1992; 1997a,b): This paper presents a research program that not only examined motion sickness associated with use of head mounted displays in virtual environments but also ways to improve virtual environments to avoid sickness. The head mounted display itself does not cause the problem, symptoms can start with an exposure of only 15 minutes but in some cases, it will also decay within 15 minutes after the exposure. Suggestions include improving visual delay between head motion and system response and asking subject to limit head movements.

DiZio & Lockner (2002): This book chapter is a review of their other work on the physical effects of virtual environment use. The authors point out that using an immersed virtual environment may have physical effects in the initial adaptation and then subsequent return to reality.

f) Magee (1997): A virtual reality simulator of a ship was created. Twenty-six students participated in a longitudinal study. Over 4 sessions, all students demonstrated increased learning and ability to transfer their training to a real shipboard situation. However, no control group was used and many suffered simulator-induced illness.

g) Stoffregen, Draper, Kennedy, & Compton (2002): This chapter gives a good overview of research focused on vestibular adaptation. Incorrectly calibrated head trackers can influence vestibulo-occular reflex reactions.

Virtual environments for individuals seem better developed than those for teams. However, this is not surprising because the technology needed in order to create an environment where multiple players can interact is still developing.

Although simulations such as those described in the team section are becoming more advanced, the physical aspects (particularly tactile) are difficult to simulate for multiple individuals concurrently and in real time. To have one individual interacting with simulated team members seems easier than having many real team members interacting within a virtual environment in real time. (Note that an individual interacting with simulated team members can still have a huge benefit – both for the individual and for the people who want to train that individual. It is often extremely difficult to assemble all the relevant people needed for team training.) Technology and research on team virtual learning environments will need to address the large quantity of sensory data (both from the environment and from all the team members actions and interactions) (Fisher, 2002).[4]

Medicine and Education

Both medicine and education have focused much attention on integrating new technology to improve training. In addition, medicine has many common features to military training. For example, training in medicine can be high stakes, with the safety of the patient paramount. Further, medicine requires both adherence to a hierarchy of command but also teamwork at various levels. With high costs, many rural areas cannot afford full medical facilities and therefore distance training and even distance procedures are being examined. Although summarized briefly in this section, the developments in these areas over the next few years, combined with developments in pure technology areas, could inform the military in their own advancements in virtual learning environments.

Medicine has used real actors to simulate patients (Adams, 2003; Barrows, 1985, 1993; Harden & Collins, 1998; Ker et al., 2005) but computer simulations can not only create adequate substitutions but also repeatable clinical experiences (Objective Structural Clinical Exams – OSCE – Bradley & Humphris, 1999; Kaufman et al., 2000; Medina, Racadio, & Schwid, 2000; Shaffer, Gordon & Bennett, 2004). Thus, the use of fully simulated (computer) patients has become more routine (for survey see Liu, Tendick, Cleary & Kaufmann, 2003). For example, Hemman (2005) evaluated a simulation of a virtual patient in combat medic training. Three classes used the virtual patient for training and the other three classes had traditional training. Although no differences were found, this study is fairly unique because it summarizes an actual

---

[4] The literature on teamwork has more studies using simulations or synthetic task environments. Virtual learning environments where teams are immersed in virtual reality are hard to find. One exception is Brna & Aspin (1998) but this study is extremely exploratory with a very small group of dyads and no real learning evaluation. Another example is Hudson, Helser, Sonnenwald & Whitton (2003) in which a collaborative virtual environment, not immersive, was used collaboratively and at a distance by groups of students. The system was a collaborative science work experience but not a training system. However, it does demonstrate that such a system can be created (although the immersive nature is still not validated).

evaluation and may indicate that the use of simulators can aid in the training of future medics with detriments.

The advancement of technology has also allowed for surgeons to perform surgeries at a distance (Eadie, Seifalian, Davidson, 2003; Jones, 1997). Although most studies report success (Eadie et al., 1997), improvements in technology and training students on how to use such technology are needed to advance the field. In addition, evidence that virtual reality training can improve surgical performance can be found in several publications (see Cosman, Cregan, Martin, & Cartmill, 2002; Harir, Srivastava, Youngblood, & Ladd, 2004; Seymour et al., 2002) and can in some cases transfer that training to a real life situation (Seymour et al., 2002); but more work needs to be done to extensively compare current methods with virtual methods (Cosman et al., 2002). The inclusion of haptic devices, has made surgical training more realistic and effective (Liou et al., 2003); however, these are still not immersive, with simulations of surgical team members. (Note that virtual reality can also be used to train patients. For example, Pons et al. (2005) used virtual reality to train patients who had lost a limb to use a hand prosthesis. Other studies are described in Holden & Todorov (2002).)

Teamwork is also becoming a focus in medical education (Clark, Leinhaas, & Filinson, 2002). Although virtual reality/virtual learning environments do exist in medical education (see for a review, Satava & Jones, 2002), the combination with teamwork and distributed training is hard to find in printed journal articles. Evaluation of applications of virtual reality to both group/team training and medicine are starting to appear in the conference literature and should start appearing in publications soon (see Shaffer et al., 2004 for ideas about evaluation).

In education, team learning has often been referred to as collaborative learning or small group learning (for one review see Johnson, Johnson & Smith, 1991; Springer, Stanne & Donovan, 1999). The ideas have moved from the classroom to the web. Although web-based distance learning has recently become popular, the vast majority of the students still attend classes at a campus and multimedia, as well as web-based distance learning, is used more as a supplement (Schulz & Dahale, 1999). Successful training using multimedia learning is well-documented (see work by Mayer for multimedia instruction.) However, in general, evaluations in web-based learning and applications found in schools or other educational venues, tend to focus on satisfaction more than on learning outcomes and therefore, as with all areas, more evaluative research is needed.[5] On the other hand, although simulations and web/distance learning have been adapted to a certain extent (Anderson & Jackson, 2000), virtual environments have not been so easily integrated. To start, virtual learning environments can mean many things to many authors/researchers. For example, Akeroyd (2005), defines many systems used in the UK as virtual learning

[5] Distance learning has been used in education for quite a long time. Navarro & Shoemaker (2000) argue that most evaluations and opinions are still based upon the oldest technologies. Their studies show that web-based learning can be effective, however, again, they have not evaluated immersive virtual environments.

environments, but does not really mean the use of virtual reality, so much as that the participants are virtual (i.e., not present). He discusses the benefits and authoring issues involved with essentially web-based distance learning; however, virtual reality is not really included.[6] Thus, some common terminology needs to be imposed in order to be able to equate work across disciplines.

Another issue is that the technology needed for students at a distance to have a true virtual experience is too expensive to be widely available. Further, groupware has not always been the focus of attention (Anderson & Jackson, 2000). Whitworth (2005) argues that either instructors are not adopting or they are adopting and not publicizing. In either case, evaluative research for virtual learning environments has not appeared as readily in the literature.[7] It is likely that virtual environments on campus will appear before distance virtual environments but both developments will depend upon advancements in technology.

From a quick read of these areas, medicine and education, it is clear that advances in virtual learning environments and evaluations of systems developed in these areas, are likely to be very promising and any future researchers should pay attention to innovations in these areas.

Recommendations for promising areas of research with a discussion of the problems and scalability of these approaches for current Air Force training practices.

Potential advantages

As technology improves and becomes less expensive, it may become more viable to have immersive virtual environments at a distance and with teams and the individuals' experiences may be no different from when they are training individually in one location.

• VLE can provide a more realistic environment. They allow for the individual and team members to have more repetitions on task. (see Shaffer et al., 2004)

• Improved distance and team VLE could allow for an expert (or instructor) to be available to interact virtually. (More than one expert/instructor might also be available).

---

[6] Other researchers have also used virtual learning environment merely to mean students (and teachers) working on the internet rather than a classroom (see Weller, Pegler & Mason, 2005, for another example). Thus, definition is a continual problem when researching these issues.

[7] In a pilot study, Johnson, et al. (1998) evaluated an immersive virtual environment for educating students that merely presents a fantasy world for them to explore. Pairs of students at different locations with a teacher represented in the virtual space were tested using the environment. The study merely demonstrated that students could navigate and use the system but didn't test learning.

•These systems may be able to embody the information of experts' knowledge and feedback more easily and have a virtual expert available at all times.

•Improved distance learning can actually provide more interaction possibilities.

Potential problems

•Better technology is needed for many reasons. First, the network connections need to be faster and more reliable than they are right now. In some cases, access to connections may also be an issue. Second, technology is rapidly changing and therefore the infrastructure must be setup to adapt to these changes. Third, there is often not enough funding for upkeep or enough specialized individuals to keep the technology working.

•Assessment: More assessment needs to be performed at all levels. In order to make sure that both learners and instructors can use the equipment (human-computer interface usability). This needs to go beyond satisfaction. Virtual learning environments also need to be examined for how well learners acquire the skills and knowledge that they need. Immersive virtual learning environments need to be compared to learning the same skills and knowledge in the real world (classes, field training, etc.), against synthetic task environments, and non-immersive virtual reality. Finally, the systems need to be evaluated for whether learners can transfer their skills and knowledge to the real world.

•More research has been performed on individuals using immersive learning environments. However, even if learning and transfer is established for individuals (either in co-located or distributed learning environments), findings for individuals may not translate to teams. Therefore some additional research may be needed for team training in distributed virtual learning environments.

•In distributed training, asynchronous connections between an instructor and learner is assumed. However, with synchronous, immersed learning environments, it may be difficult to manage the teams of learners and they may expect the instructor to be present.

•Cultural needs of learners who are at a distance may need to be taken into account, especially if they are in different countries (Bryant & Davis, 2005; Helmreich & Merritt, 1998).

•The cost may be too high (especially for schools) for both development and appropriate evaluation. (Extensive evaluation, especially whether people actually learn from a training system, is often not performed because there's a push to get a system in the field.)

•Because many locations where a distributed training system might be used have different types of hardware (and sometimes even different software), cross-platform issues need to be taken into account.

•There's a lack of standards in the field (see also Shaffer et al., 2004; Stytz & Banks, 1998).

•The time to train individuals and instructors might be high given the complexity of such systems (see Pajo, 2001).

Other issues

One of the problems with examining a topic such as virtual learning environments is that many fields are trying to develop and integrate virtual reality into their general systems and education/training curriculums. The terminology across areas is often slightly different. In this paper, we did our best to summarize published works but some items might have been missed if they were not using the same terminology, and, as before, some items appear in conference proceedings but have not gone through the rigorous evaluation of journal acceptance. Although this paper did briefly cover medicine and education (though not extensively), the gaming arena is constantly developing new and better technology (Hall, Hong, Marshall, Garrity, & Green, 2005) to satisfy customers' demands. This creates a new area of research – the adaptation of software developed for commercial applications (and systems) to military ones. (See Bakker & Button, 2003, for an example of integrating a synthetic training environment with existing systems.) Although not insurmountable, the differences can still be extensive.

Future Directions

The ideal system would be a virtual environment in which individuals or teams could learn or practice what they know. Individuals or team members would all be immersed and interact as if they were in the real world. The system would have to contain ways for team members to communicate both verbally and non-verbally. It would have to include a background tutoring system that models ideal behavior and can provide corrective feedback. (For team training this would be quite difficult because each team member would have to be monitored, along with the overall team performance.) The system would be able to work in a distance fashion much as MOOs[8]. This would allow teams to train before they arrive to do a job. Finally, all of these aspects would be evaluated for their ability to train people and not just for user satisfaction. The following paragraphs describe different issues that still need to be addressed within this vision.

---

[8] MOOs are network accessible, multi-user, programmable, interactive systems well-suited to the construction of text-based adventure games, conferencing systems, and other collaborative software. Their most common use, however, is as multi-participant, low-bandwidth virtual realities (Wikpedia, 2006). Ideally, we would want high-bandwidth virtual realities for this situation. (See Schalger, Fusco, & Schank, 1998 for a description of one MOO.)

The most important aspect of any virtual environment system is the ability to transfer the knowledge learned to the performance in the real world. Virtual learning environments have had many benefits for learners (Rose et al., 2000), however, only transfer of sub-skills has been demonstrated but overall transfer to real-world environments has not been validated (Brooks, Attree, Rose, Clifford, & Leadbetter, 1999; Cohn, Helmick, Meyers & Burns, 2000; Witmer, Bailey, & Knerr, 1996; Witmer & Sadowski, 1998).

What is needed in the intersection of virtual learning environments and team training? Improvements in simulations and hardware are needed for true virtual learning environments. It's not that training systems don't exist but that they could be vastly improved (see results from Tromp et al., 2003). The issues are different if the training system is supposed to supply the other team members (virtual humans; see Garau et al., 2005) or whether all the real human team members will be represented in the virtual environment for training. This last possibility would allow for distance team training in a virtual environment. In both cases, though, the technology has more work to do before a virtual human will be viewed in the same way as a real human.

A true training system would constantly monitor the learner (or learners) and provide feedback. For example, feedback would necessitate a way to analyze the team's performance as it is happening. Both the actions of the team need to be analyzed as they occur and the communication of the team members. New technology such as those proposed by Foltz (Foltz, et al., 2003; Foltz & Martin, 2004; Foltz, et al., 2006) needs to be integrated into existing technologies.

Aside from system improvement, the integration of learning technologies from developers to adapters is often difficult. Distance training can be even more difficult because systems at different sites need to be coordinated. Further instructors need to be trained both at location with current technology and across sites to coordinate curriculum and training issues.

Research is needed to improve both virtual environments generally and virtual learning environments in particular, in order to both create and demonstrate transfer of training. There is no doubt that government sponsored research and technology corporations will continue to develop better hardware and software for the task (see Hall et al., 2005, for commentary); however, aside from research that merely creates new and better virtual environments, virtual learning environments, focus on evaluation (whether something was learned and not merely "liked") is needed in order to demonstrate that these systems really produce learning.

References

These articles were cited in this document.

Adams, G. (2003). Simulated and standardized patients in OSCEs: Achievement and challenges 1992-2003. *Medical Teacher*, *25*, 262-270.

Akeroyd, J. (2005). Information management and e-learning: Some perspectives. Aslib *Proceedings New Information Perspectives*, *57*(2), 157-167.

Anderson, J.R., Corbett, A.T., Koedinger, K.R., & Pelletier, R. (1995). Cognitive tutors: Lessons learned. *The Journal of the Learning Sciences*, *4*(2), 167-207.

Anderson, J. R. & Gluck, K. (2001). What role do cognitive architectures play in intelligent tutoring systems? In D. Klahr & S. M. Carver (Eds.) *Cognition & Instruction: Twenty-five years of progress*. (pp. 227-262). Norwood, NJ: Erlbaum.

Anderson, M., & Jackson, D. (2000). Computer systems for distributed and distance learning. *Journal of Computer Assisted Learning*, *16*, 213-228.

Aptima Corporation. http://www.aptima.com/military_command_and_control.php

Arnold, P., Martin, J.F., Pettifer, S., & West, A.J. (20002). Performance of a skilled motor task in virtual and real environments. *Ergonomics*, *45*(5), 348-361.

Bakker, K., & Button, C. (2003). "Train as you fight", Integrating the Army's aviation mission planning system with AVCATT-A. *Proceedings of I/ITSEC*. Orlando, FL.

Barrows, H.S. (1985). *How to design a problem-based curriculum for the pre-clinical years*. NY: Springer.

Barrows, H.S. (1995). An overview of standardized patients for teaching and evaluating clinical skills. *Academic medicine*, *68*, 443-453.

Barry, M., & Ryan, G.B. (1995). A review of distance-learning studies in the U.S. Military. *The American Journal of Distance Education*, *9*(3), 37-45.

Beranek, P.M., & Martz, B. (2005). Making virtual teams more effective: Improving relational links. *Team Performance Management*, *11* (5/6), 200-213.

Boling, N.C., & Robinson, D.H. (1999). Individual study, interactive multimedia, or cooperative learning: Which activity best supplements lecture-based distance learning? *Journal of Educational Psychology*, *91*(1), 169-174.

Bradley, P., & Humphris, G. (1999). Assessing the ability of medical students to apply evidence in practice: The potential of the OSCE. *Medical Education*, *33*(11), 815-817.

Brooks, B.M., Attree, E.A., Rose, F.D., Clifford, B.R., & Leadbetter, A.G. (1999). The specificity of memory enhancement during interaction with a virtual environment. *Memory*, *7*, 65-78.

Bryant, J.L., & Davis, D.D. (2005). Cultural differences in situational awareness, shared mental model, and workload perceptions: An analysis of American and Chinese simulated flight crews. 2004-2005 Aerospace Graduate Research Fellows and Aerospace Undergraduate Research Scholars Abstracts and Research Papers. Virginia Space Grant Consortium.

Brna, P., & Aspin, R. (1998). Collaboration in a virtual word: Support for conceptual learning? *Education and Information Technologies*, *3*, 247-259.

Calvani, A., Sorzio, P. & Varisco, B. (1997). Inter-university cooperative learning: An exploratory study. *Journal of Computer Assisted Learning*, *13*, 271-280.

Cannon-Bowers, J., & Salas, E. (1998). Individual and team decision making under stress: Theoretical underpinnings. In J.A. Cannon-Bowers & E. Salas (Eds.), *Making Decisions Under Stress: Implications for Inidivdual and Team Team Training* (pp. 17-38). Washington, DC: American Psychological Association.

Cannon-Bowers, J.A., Salas, E., Blickensderfer, E., & Bowers, C.A. (1998). The impact of cross-training and workload on team functioning: A replication and extension of initial findings. *Human Factors*, *40*, 92-101.

Card, S.K., Moran, T.P., & Newell, A. (1983). *The Psychology of Human-Computer Interaction*. Hillsdale, NJ: Erlbaum.

Clark, P.G., Leinhaas, M.M., & Filinson, R. (2002). Developing and evaluating an interdisciplinary clinical team training program: Lessons taught and lessons learned. *Educational Gerontology*, *28*, 491-510.

Cobb, S.V.G., Nichols, S., Ramsey, A., & Wilson, J.R. (1999). Virtual reality-induced symptoms and effects (VRISE). *Presence*, *8*(2), 169-186.

Cohn, J.V., Helmick, J., Meyers, C., & Burns, J. (2000). Training-transfer guidelines for virtual environments. Presented at 22nd Annual I/ITSEC conference. Orlando, FL.

Cooke, N. J. (2005). Measuring team knowledge. *Handbook on Human Factors and Ergonomics Methods* (pp. 491-496). Boca Raton, FL: CLC Press, LLC.

Cooke, N. J., Salas, E., Cannon-Bowers, J. A., & Stout, R. (2000). Measuring team knowledge. *Human Factors, 42*, 151-173.

Cooke, N. J., & Shope, S. M. (2004), Designing a synthetic task environment. In S. G. Schiflett, L. R. Elliott, E. Salas, & M. D. Coovert (Eds.), *Scaled Worlds: Development, Validation, and Application* (pp. 263-278). Surrey, England: England: Ashgate.

Corbett, A.T., Koedinger, K.R., & Anderson, J.R. (1997). Intelligent tutoring systems (Chapter 37). In M.G. Helander, T.K. Landauer, & P.Prabhu, (Eds.), *Handbook of Human-Computer Interaction*. 2nd edition. Amsterdam, The Netherlands: Elsevier Science.

Cosman P.H.; Cregan P.C.; Martin C.J.; Cartmill J.A. (2002). Virtual reality simulators: Current status in acquisition and assessment of surgical skills. *ANZ Journal of Surgery*, *72*(1), 30-34.

Danielsson, J., Banushkina, P., Nutt, D., & Meuwly, M. (2006). Computer simulation of structures, energetics, and dynamics of myoglobin—ligend complexes. *International Reviews in Physical Chemistry*, *25*(3), 407-425.

DiZio, P., & Lackner, J.R. (1992). Spatial orientation, adaptation and motion sickness in real and virtual environments. *Presence*, *1*(3), 319-328.

DiZio, P., & Lackner JR. (1997). Circumventing side effects of immersive virtual environments. In M.J. Smith, G. Salvendy & R.J. Koubek (Eds.), *Advances in*

Human Factors/Ergonomics. Vol. 21 Design of Computing Systems. Amsterdam: Elsevier. (pp. 893-397).
DiZio, P., & Lackner JR. (1997b). Motion sickness side effects and aftereffects of immersive virtual environments created with helmet-mounted visual displays. In RTO HFM Workshop on "The capability of virtual reality to meet military requirements. Orlando, FL..
DiZio P, & Lackner JR. (2002). Proprioceptive adaptation and aftereffects. In Stanney K (Ed), *Handbook of virtual environments*. (pp. 751-771). NY: Lawrence Erlbaum Associates, NY (pp. 751-771).
Dornheim, M.A. (2000). Pilots hone teamwork skills in 'long haul' virtual linkup. *Simulation and Training*, *153*(200), 58-61.
Driskell, J. E., & Salas, E. (1991). Group decision making under stress. *Journal of Applied Psychology*, *76*, 473-478.
Druckman, D. (2004). Be all that you can be: Enhancing human performance. *Journal of Applied Social Psychology*, *34*, 2234-2260.
Durlach, N., Allen, G., Darken, R., Garnett, R.L., Lomis, J., Templeman, J., & von Wiegand, T.E. (2000). Virtual environments and the enhancement of spatial behavior: Towards a comprehensive research agenda. *Presence*, *9*(6), 593-615.
Dwyer, D.J., Oser, r.L., Salas, E., & Fowlkes, J.E. (1999). Performance measurement in distributed environments: Initial results and implications for training. *Military Psychology*, *11*(2), 189-215.
Eadie, L.H., Seifalian, A.M., & Davidson, B.R. (2003). Telemedicine in surgery. *British Journal of Surgery*, *90*(6), 647-658.
Ellaway, R., Dewhurst, D., & McLeod, H. (2004). Evaluating a virtual learning environment in the context of its community of practice. ALT-J, Research in Learning Technology, 12(2), 125-145.
Ellis, A.P.J., Hollenbeck, J.R., Ilgen, D.,R., Porter, C.O.L.H., West, B.J., & Moon, H. (2003). Team learning: Collectively connecting the dots. *Journal of Applied Psychology*, *88*(5), 821-835.
Ellis, C. A., Gibbs, S. J., & Rein, G. L. (1991). Groupware: Some issues and experiences. *Communications of the ACM*, *34*(1), 38-58.
Fisher, S.S. (2002). An authoring toolkit for mixed reality experiences. International Workshop on Entertaining Computing: Special Session on Mixed Reality Entertainment. Tokyo, Japan, May 14-17.
Foltz, P. W., Laham, R. D. & Derr, M. (2003). Automated Speech Recognition for Modeling Team Performance. In *Proceedings of the 47th Annual Human Factors and Ergonomic Society Meeting*.
Foltz, P. W. & Martin, M. A. (2004) Automated team discourse annotation and performance prediction using LSA. In *Proceedings of the Human Language Technology conference / North American chapter of the Association for Computational Linguistics annual meeting HLT/NAACL 2004*.

Foltz, P. W., Martin, M. A., Abdelali, A., Rosenstein, M. B. & Oberbreckling, R. J. (2006). Automated Team Discourse Modeling: Test of Performance and Generalization. In *Proceedings of the 28th Annual Cognitive Science Conference*.

Frost, P.J., & Fukami. C.V. (1997). Teaching effectiveness in the organizational sciences: Recognizing and enhancing the scholarship of teaching. Academy of Management Journal, *40*(6), 1271-1281.

Furness III, T.A., Winn, W., & Yu, R. (1997). The Impact of Three Dimensional Immersive Virtual Environments on Modern Pedagogy: Global Change, VR and Learning. Report of Workshops Held in Seattle, Washington and at the University of Loughborough, England in May and June.

Garau, M., Slater, M., Pertaub, D. & Razzaque, S. (2005). The responses of people to virtual humans in an immersive virtual environment. *Presence*, *14*(1), 104-116.

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. Human Factors, *36*, 387-405.

Hahn, H. (1990). Distributed training for the reserve component: Remote delivery using asynchronous computer conferencing. Report No. 2Q263743A794. Boise, ID: Army Research Institute.

Hall, C.R., Stiles, R.J., & Horowitz, C.D. (1998). Virtual reality for team training: Evaluating knowledge retention. *IEEE 1998 Virtual Reality Annual International Symposium*. Atlanta, GA.

Hall, G., Hong, D., Marshall, H., Garrity, P., & Green, G. (2005). Embedded training alternatives for future dismounted forces – An evaluation of gamining and simulation engines for embedded simulation. *Proceedings of I/ITSEC 2005*. Orlando, FL.

Hamilton, R. (2005). Nurses' knowledge and skill retention following cardiopulmonary resuscitation training: A review of the literature. *Journal of Advanced Nursing*, *51*, 288-297.

Hariri, S., Rawn, C., Srivastava, S., Youngblood, P., & Ladd, A.. (2004). Evaluation of a surgical simulator for learning clinical anatomy. *Medical Education*, *38*(8), 896-902.

Harden, R.M., & Collins, J.P. (1998). AMEE Medical Education Guide No 13, Real patients, simulated patients, and simulators in clinical examination. *Medical Teacher*, *20*, 508-51.

Harm, D.L. (2002). Motion sickness neurophysiology, physiological correlates, and treatment. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and application*s. (pp. 637-661). Mahwah, NJ: LEA.

Hartley, J. & Sleeman, D. (1973). Towards more intelligent teaching systems. *International Journal of Man-Machine Studies, 2*, 215-236.

Hedlund, J., Ilgen, D.R., & Hollenbeck, J.R. (1998). Decision accuracy in computer-mediated versus face-to-face decision making teams. *Organizational and Behavior and Human Decision Processes*, *76*, 30-47.

Heldal, I., Steed A., Spante M., Spante, M., & Schroeder, R. (2005). Successes and failures in copresent situations. *Presence: Teleoperators in Virtual Environments*, *14*(5), 563-579.

Helmreich, R.L., & Merritt, A.C. (1998). *Culture at work in aviation and medicine: national organizational, and professional influences*. Brookfield, VT: Ashgate.

Hemman, E.A. (2005). Improving combat medic learning using a personal computer-based virtual training simulator. *Military Medicine*, *170*(9), 723-727.

Holden, M.K., & Todorov, E. (2002). Use of virtual environments in motor learning and rehabilitation. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 999-1026). Mahwah, NJ: LEA.

Honebein, P.C. (1996) Seven goals for the design of constructivist learning environments. In B.G. Wilson (Ed.), *Constructivist learning environment: Case studies in instructional design*. (Chapter 2). Englewood Cliffs, NJ: Educational Technology Publications.

Hudson, T.C., Helser, A.T., Sonnewald, D.H., & Whitton, M.C. (2003). Managing collaboration in the nanoManipulator. *Proceedings of the IEEE Virtual Reality 2003 Conference*. Los Angeles, CA.

Johnson, D., Johnson, R., & Smith, K. (1991), Cooperative Learning: Increasing College Faculty Instructional Productivity. ASHE-ERIC Higher Education Report No. 4, Washington, DC: The George Washington University.

Johnson, A., Roussos, M., Leigh, J., Vasilakis, C., Barnes, C., Moher, T. (1998). The NICE Project: Learning together in a virtual world. *Proceedings of the IEEE 1998 Virtual Reality Annual International Symposium*. Atlanta, GA.

Jones, S.B. (1997). Surgery 2001. In R.J. Seidel, & P.R. Chatelier (Eds.), *Virtual reality, training's future? Perspective on virtual reality and related emerging technologies*. (pp. 65-67). NY: Plenum Press.

Kerka, S. (1996). Distance learning, the Internet, and the World Wide Web. ERIC Digest no. 168. ED 395 214. Columbus: ERIC Clearinghouse on Adult, Career, and Vocational Education, the Ohio State University.

Kaufman, d.M., Mann, K.V., Muijijens, A.M., & van der Vleuten, C.P. (2000). A comparison of standard-setting procedures for an OSCE in undergraduate medical education. *Academic Medicine*, *75*(3), 267-271.

Kiperman, E., Sirkis, A., & Popovich, E. (2005). Developing a low intensity conflic urban simulation: Lessons learned. *Proceedings I/ITSEC*. Orlando, FL.

Kline, J. & McGrath, J. (1999). A review of the groupware literature: Theories, methodologies and a research agenda. *Canadian Psychology, 40*.

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, *8*, 30-43.

Kozak, J.J., Hancock, P.A., Arthur, P.J. & Chrysler, S.T. (1993). Transfer of training from virtual environment. *Ergonomics*, *36*, 777-784.

Lawson, B.D., Graeber, D.A., Mead, A.M., & Muth, E.R. (2002). Signs and symptoms of human syndromes associated with synthetic experiences. In K.M. Stanney

(Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 589-618). Mahwah, NJ: LEA.
Lee, A.Y., Bond, G.D., Scarbrough, P., Gillan, D., & Cooke, N. (2006). Team training and transfer in differing contexts. Manuscript submitted for consideration *Applied Cognitive Psychology*.
Levine, J.M., & Mooreland, R.L. (1990). Progress in small group research. In M.R. Rosenzweig & L.W. Porter (Eds.), *Annual Review of Psychology*, *41*, 585-634.
Linebarger, J.M., Janneck, C., & Kessler, G.D. (2004). "Leaving the World Behind:" Supporting group collaboration patterns in a shared virtual environment for product design. Manuscript submitted for consideration to *Presence*.
Liu, A., Tendick, F., Cleary, K. & Kaufmann, C.R. (2003). A survey of surgical simulation: Applications, technology, and education. *Presence*, *12*(6), 599-614.
Loughran, J.J. (1998). Evaluating aggregated performance data from distributed simulation training exercises. *Simulation Series*, *30*(2), 199-206.
Medina, L.S., Racadio, J.M., & Schwid, H.A. (2000). The sedation, analgesia, and contrast media computerized simulator: A new approach to train and evaluate radiologists' responses to critical incidents. *Pediatric Radiology*, *30*, 299-305.
Magee, L.E. (1997). Virtual reality simulator (VRS) for training ship handling skills. In R.J. Seidel & P.R. Chatelier (Eds.), *Virtual reality, training's future?: Perspectives on virtual reality and related emerging technologies*. (pp. 19-29). NY: Plenum Press.
Malone, B. (2006). A simulation based design environment for network centric warfare using distributed analysis. http://www.phoenix-int.com/SimulationBasedDesign.htm
Mantovani, G. (1996). *New communication environments from everyday to virtual*. Bristol, PA: Taylor & Francis.
Marriott, N. (2004). Using computerized business simulations and spreadsheet models in accounting education: a case study. *Accounting Education*, *13*(1), 55-70.
MacDonald, J. (2005). Rules of engagement: Fostering active learning for performance improvement. *Proceedings of I/ITSEC*. Orlando, FL.
Macredie, R., Taylor, S.J.,E., Yu, X., & Keeble, R. (1996). Virtual reality and simulation: An overview. In J.M., Charness, D.J., Morrice, D.T., Brunner, & J.J. Swain (Eds.), *Proceedings of the 1996 winter Simulation Conference*. (pp. 669-674).
McCann, c., Baranski, J.V., Thompson, M.M., & Pigeau, R.A. (2000). On the utility of experiential cross-training for team decision-making under time stress. *Ergonomics*, *43*(8), 1095-1110.
Middleton, V.E., McIntyre III, R.T., O'Keefe IV, J. (1993). Virtual reality and analytical simulation of the soldier. In G.W. Evans, M. Mollaghasemi, E.C. Russell, & W.E. Biles (Eds.), *Proceedings of the 1993 Winter Simulation Conference*.
Navarro, P., & Shoemaker, J. (2000). Performance and perception of distance learners in cyberspace. *The American Journal of Distance Education*, *14*(2), 15-35.
Nishinosono, H. (1992). A design method for classroom instruction in the multimedia environment. In M. Giardina, *Interactive Multimedia Learning Environments* (pp.31-38). Berlin: Springer-Verlag.

North, M.M., North, S.M., & Coble, J.R. (20002). Virutal reality therapy: An effective treatment for psychological disorders. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 1065-1078.) Mahwah, NJ: LEA.

O'Keefe, J.A. IV, & McIntyre III, R.T. (2006). Virtual assessment environment for individual combatant systems. Web http://www.cs.odu.edu/~tang_j/phd/doc/sympdf/061.pdf.

Olson, G., & Olson, J. (1991). User-Centered design of Collaboration technology". *Journal of Organizational Computing*, *1*, 61-83.

Pajo, K. (2001). Barriers to the uptake of web-based technology by university teachers. *Journal of Distance Education*, *16*(1), 70-84.

Paris, C.R., Salas, E., & Cannon-Bowers, J.A. (2000). Teamwork in multi-person systems: A review and analysis. *Ergonomics*, *43*(8), 1052-1075.

Park, K.S., & Kenyon, R.V. (1999). Effects of network characteristics on human performance in a collaborative virtual environment. *Proceedings of IEEE Virtual Reality conference*. Houston, TX.

Pons, J.L., Ceres, R., Rocon, E., Levin, S., Markovitz, I., Saro, B., Reynaerts, D., Van Moorleghem, W. & Bueno, L. Virtual reality training and EMG control of the MANUS hand prosthesis. *Robotica*, *23*, 311-317.

Regan, C. (1997). Some effects of using virtual reality technology: Data and suggestions. In Seidel & Chatelier (Eds.), *Virtual reality, training's future?* NY: Plenum Press.

Regian, J.W. (1997). Virtual reality for training: Evaluating transfer. In Seidel & Chatelier (Eds.), *Virtual Reality, Training's Future?* NY: Plenum Press.

Regian, J.W., & Shebilske, W.L (1992). Virtual reality: An instructional medium for visual-spatial tasks. *Journal of Communication*, *42*(4), 136-149.

Rose, F.D., Attree, E.A., Brooks, B.M., Parslow, D.M., Penn, P.R., & Ambihaipahan, N. (2000). Training in virtual environments: Transfer to real world tasks and equivalence to real task training. *Ergonomics*, *43*, 494-511.

Salas, E., Burke, C.S., Bowers, C.A., & Wilson, K.A. (2001). Team training in the skies: does crew resource management (CRM) training work? *Human Factors*, *43*(4), 641-674.

Salas, E., Bowers, C.A., & Cannon-Bowers, J.A. (1995). Military team research: 10 years of progress. *Military Psychology*, *7*(2), 55-75.

Salas, E., Cannon-Bowers, J. A., & Johnston, J. H. (1997). How can you turn a team of experts into an expert team?: Emerging training strategies. In C. Zsambok & G. Klein (Eds.), *Naturalistic decision making* (pp. 359-370). Hillsdale, NJ: LEA.

Salas, E., Dickinson, T.L., Converse, S.A., & Tannenbaum, S.I. (1992). Toward an understanding of team performance and training. In R.W. Swezey and E. Salas (Eds.), *Teams: Their training and performance* (pp. 3-29). Norwood, NJ: Ablex.

Satava, R.M., & Jones, S.B. (2002). Medical applications of virtual environments. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 937-957). Mahwah, NJ: LEA.

Schlager, M., Fusco, J., & Schank, P. (1998). Conceptual cornerstones for an on-line community of education professionals. *IEEE Technology and Society, Special Issue on Computers in the Classroom: The Internet in K-12*, *17*(4), 15-21.

Schultz, K.C., & Dahale, V. (1999). Multimedia modules for enhancing technical laboratory sessions. *Campus-Wide Information Systems*, *16*, 81-88.

Schwameder, H., & Muller, E. (2001). Biomechanics in ski jumping: A review. European *Journal of Sport Science*, *1(*1), pp. 1-16.

Seymour, N., Gallagher, A., Roman, S., O'Brien, M., Bansai, V., Anderson, D., & Satava, R. (2002). Virtual reality training improves operating room performance. *Annals of Surgery*, *236*(4), 458-464.

Shaffer, D.W., Gordon, J.A., & Bennett, N.L. (2004). Learning, testing, and the evaluation of learning environments in medicine: Global performance assessment in medical education. *Interactive Learning Environments*, *12*(3), 167-178.

Sikes, C.S., Cherry, A.K., Durall, W.K., Hargrove, M.R., & Tingman, K.R. (1996). Brilliant warrior: Information technology integration in education and training. Research paper presented to Air Force 2025. http://www.au.af.mil/au/2025/volume1/chap10/v1c10-1.htm.

Simpson, H. (1999a). Evaluating large-scale training simulations. Volume I: Reference manual. DMDC TR 99-05. Seaside, CA: Defense Manpower Data Center.

Simpson, H. (1999b). Evaluating large-scale training simulations. Volume II: User's manual. DMDC TR 99-06. Seaside, CA: Defense Manpower Data Center.

Slater, M., Sadagic, A., Usoh, M., & Schroeder, R. (2000). Small-group behavior in a virtual and real environment: A comparative study. *Presence*, *9*(1), 37-51.

Sleman, D.H. & Brown, J.S. (1982). *Intelligent tutoring systems*. London: Academic Press.

Springer, L, Stanne, M.E., & Donovan, S.S. (2005). Effects of small-group learning on undergraduates in science, mathematics, engineering, and Technology: A meta-analysis. *Review of Educational Research*, *69*(1), 21-51.

Sproull, L., & Kiesler, S. (1986). Reducing social context cues: Electronic mail in organizational communication. *Management Science*, *32*, 1492-1512.

Stanney, K.M. (2002). *Handbook of virtual environments: Design, implementation, and application*s. Mahwah, NJ: LEA.

Stata, R. (1989). Organizing learning: The key to management innovation. *Sloan Management Review*, *30*, 63-74.

Steed, a., Slater, M., Sadagic, A., Bullock, A., & Tromp, J. (1999). Leadership and collaboration in shared virtual environments. *Proceedings of the IEEE Virtual Reality conference*. Houston, TX.

Stoffregen, T.A., Draper, M.H., Kennedy, R.S., & Compton, D. (2002). Vestibular adaptation adaptation and aftereffects. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 773-790). Mahwah, NJ: LEA.

Stytz, M.R., & Banks, S.B. (1998). Requirements and architecture for distributed threat systems for aircrew mission training. *Simulation Series, 30*(4), 123-129.
Tate, D.L., Sibert, L., & King, T. (1997). Using virtual environments to train firefighters. *IEEE Computer Graphics and Applications*, 23-29.
Thurston, P.W., & Earnhardt, C.C. (2003). Going further with e-learning: Factors influencing persistence, transfer and intentions to continue. Proceedings of the Interservice/Industry Training, Simulation, and Education Conference.
Tobias, S., & Fletcher, J.D. (2000). *Training and retraining*. Washington, DC: APA.
Tromp, J.G., Steed, A., & Wilson, J.R. (2003). Systematic usability evaluation and design issues for collaborative virtual environments. *Presence*, *12*(3), 241-267.
Valenzuela, M.S. (2003). A virtual environment for process management. A step by step implementation. *European Journal of Engineering Education*, *28*(4), pp. 465-481.
Virre, E., & Bush, D. (2002). Direct effects of virtual environments on users. In K.M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications*. (pp. 518-588.) Mahwah, NJ: LEA.
Weller, M., Pegler, C., & Mason, R. (2005). Students' experience of component versus integrated virtual learning environments. *Journal of Computer Assisted Learning*, *21*, 253-359.
Wenger, (1987). *Artificial intelligence and tutoring systems: Computational and cognitive approaches to the communication of knowledge*. Los Altos, CA: Morgan Kaufmann Publishers.
Whitworth, A. (2005). The politics of virtual learning environments: Environmental change, conflict & e-learning. *British Journal of Educational Technology*, *36*, 685-691.
Winfred, a., Edwards, B., Bell, S.T., Villado, A.J., Bennett, W. (2005). *Human Factors*, *47*(3), 654-670.
Witmer, B.G., Bailey, J.H., & Knerr, B.W. (1996). Virtual spaces and real world places: Transfer of route knowledge. *International Journal of Human-Computer Studies*, *45*, 413-428.
Witmer, B.G., & Sadowski, Jr., W.J. (1998). Nonvisually guided locomotion to a previously viewed target in real and virtual environments. *Human Factors*, *40*, 478-488.
Wright, M.C., & Kaber, D.B. (2005). Effects of automation of information-processing functions on teamwork. *Human Factors*, *47*, 50.