2014

A Multimedia Approach to Game-Based Training: Exploring the Effects of the Modality and Temporal Contiguity Principles on Learning in a Virtual Environment

Stephen Serge
University of Central Florida

A MULTIMEDIA APPROACH TO GAME-BASED TRAINING: EXPLORING THE
EFFECTS OF THE MODALITY AND TEMPORAL CONTIGUITY PRINCIPLES ON
LEARNING IN A VIRTUAL ENVIRONMENT

by

STEPHEN RYAN SERGE
B.S. Virginia Polytechnic Institute and State University, 2006
M.A. University of Central Florida, 2012

A dissertation submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy
in the Department of Psychology
in the College of Sciences
at the University of Central Florida
Orlando, Florida

Fall Term
2014

Major Professor: Mustapha Mouloua

ABSTRACT

There is an increasing interest in using video games as a means to deliver training to individuals learning new skills or tasks. However, current research lacks a clear method of developing effective instructional material when these games are used as training tools and explaining how gameplay may affect learning. The literature contains multiple approaches to training and GBT but generally lacks a foundational-level and theoretically relevant approach to how people learn specifically from video games and how to design instructional guidance within these gaming environments.

This study investigated instructional delivery within GBT. Video games are a form of multimedia, consisting of both imagery and sounds. The Cognitive Theory of Multimedia Learning (CTML; Mayer 2005) explicitly describes how people learn from multimedia information, consisting of a combination of narration (words) and animation (pictures). This study empirically examined the effects of the modality and temporal contiguity principles on learning in a game-based virtual environment. Based on these principles, it was hypothesized that receiving either voice or embedded training would result in better performance on learning measures. Additionally, receiving a combination of voice and embedded training would lead to better performance on learning measures than all other instructional conditions.

A total of 128 participants received training on the role and procedures related to the combat lifesaver – a non-medical soldier who receives additional training on combat-relevant lifesaving medical procedures. Training sessions involved an instructional presentation manipulated along the modality (voice or text) and temporal contiguity (embedded in the game or presented before gameplay) principles. Instructional delivery was manipulated in a 2x2

between-subjects design with four instructional conditions: Upfront-Voice, Upfront-Text, Embedded-Voice, and Embedded-Text.

Results indicated that: (1) upfront instruction led to significantly better retention performance than embedded instructional regardless of delivery modality; (2) receiving voice-based instruction led to better transfer performance than text-based instruction regardless of presentation timing; (3) no differences in performance were observed on the simple application test between any instructional conditions; and (4) a significant interaction of modality-by-temporal contiguity was obtained. Simple effects analysis indicated differing effects along modality within the embedded instruction group, with voice recipients performing better than text ($p = .012$). Individual group comparisons revealed that the upfront-voice group performed better on retention than both embedded groups ($p = .006$), the embedded-voice group performed better on transfer than the upfront text group ($p = .002$), and the embedded-voice group performed better on the complex application test than the embedded-text group ($p = .012$).

Findings indicated partial support for the application of the modality and temporal contiguity principles of CTML in interactive GBT. Combining gameplay (i.e., practice) with instructional presentation both helps and hinders working memory's ability to process information. Findings also explain how expanding CTML into game-based training may fundamentally change how a person processes information as a function of the specific type of knowledge being taught. Results will drive future systematic research to test and determine the most effective means of designing instruction for interactive GBT. Further theoretical and practical implications will be discussed.

This work is dedicated to all of my family and friends. Your constant words of encouragement and endless support were always there to keep me motivated – especially you – when I needed them the most.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION AND BACKGROUND

Training and Games

Training is a tool for providing necessary information or practice in virtually any profession or setting. People receive training when they start a new job, learn how to perform a new task, or in any situation where a new or unique skill is required for optimal performance. Simply put, training is a way to promote the learning of important information essential for a person to accomplish what is required of him or her.

Games have been used to train individuals for centuries (Smith, 2010). Historically, games have served as aids in the development of therapeutic exposure training to help overcome fears or other problems, such as childhood anxiety (Webb, 1999), to instill greater decision making abilities to those in leadership roles, such as military war gaming (Mason & Patterson, 2013), along with any number of other skills and abilities. Using games as training tools offers a fun and safe way to practice and learn in what can be an instructional and supportive environment. For instance, role-playing, in which a person acts out or responds to a scenario in a play-based fashion, allows for a deeper understanding and more precise feedback from an instructor and affords a safe and often times fun environment for the learner. Similarly, war-gaming, which refers to a type of militaristic training, allows military leaders to test the effects of different strategies without risking injury or before engaging in actual combat. The positive cost-benefit potential of game-based training outcomes can result in more effective learning and training strategies with lower overall costs, risks, and increased safety.

Over the past few decades, interest in using video games as training devices has increased dramatically. This is the result of a number of factors. First, the technology required has become

incredibly powerful at a relatively low cost, which allows for high levels of interactive game-play and intensive graphical performance at a reasonable expense. Since better virtual environment fidelity is associated with stronger transfer of knowledge (Wallet et al., 2011), the availability of low-cost, highly realistic systems is beneficial to training developers and learners alike (Dalgarno & Lee, 2010). Second, video games are exceedingly portable. This means that games are easy to distribute to a large number of people located almost anywhere. Since personal computers, handheld devices, and internet access are becoming increasingly widespread, distribution of software-based training games has never been quicker and easier. Finally, games offer a means in which to develop personalized training. The programmability and flexibility often found in today's video games allows for training that matches an individual's needs in a much more dynamic way than more generic, widespread styles of training (e.g., lectures or presentations given to hundreds of people at the same time). This means that the technology exists which allows games to be customizable to a learner's individual learning needs.

Current State of Training with Video Games

Despite the growing popularity and application of video games for training, a large gap in the literature regarding the most effective means of designing instructional game-based training exists (Baniqued et al., 2013). In most instances, games for training are developed and distributed without much attention to foundational training and learning literature. Instructional guidance within these games is either lacking or insufficiently designed to promote effective learning. This has created instances in which the effectiveness of game-based training varies across applications and has given rise to uncertainty when trying to develop a game that guides, trains, and teaches an individual the information and/or skills intended.

As such, the purpose of this research was two-fold. There are obvious areas in the research that are lacking in terms of instructional game-based training (GBT) design principles. The first goal of this research was to determine the most effective way of designing instruction within GBT systems to promote learning from gaming media. Understanding the most effective methods of teaching provides a basis that helps determine the appropriate and necessary features of instructional design that promote overall learning.

After establishing how to teach people effectively, the second goal of this study was to determine how to apply these instructional methods to interactive gaming environments designed for training. Often times, GBT removes a physical instructor, facilitator, or teacher from the learning process. Therefore, some form of guidance within a GBT system is necessary for learning to take place. This research sought to determine how to best guide the learning process within GBT environments.

Game-Based Training

Game-based training ranges from classical strategy development, such as chess, to full-fledged procedural practice and training in immersive and interactive virtual environments and simulators. No matter the medium, GBT is a tool for facilitating learning or training as a means to develop new knowledge and skills. For this effort, the focus centered on GBT that utilized video games designed for learning.

A game designed for learning consists of a specific set of characteristics. According to Mayer and Johnson (2010), these characteristics include being based on a knowable rule-set, allowing players to act and respond within the environment (i.e., be interactive), present opportunities for individuals to succeed at challenging tasks, and keep track of a player's

progress towards the goals of the game. These characteristics, while not exhaustive, provide a framework for differentiating between games for learning versus simulations.

Video games have become a popular focus for training research. Unlike larger, simulation-based trainers (e.g., full-scale mockups of cockpit flight controls or driving simulators), GBT does not typically require large workspaces or heavy and expensive equipment. Most games are developed for personal computers, web browsers, handheld devices, or popular gaming consoles, making them a relatively easy and inexpensive way to distribute training to a large number of people. In this sense, video games are a form of digital multimedia that are highly interactive (i.e., players can manipulate and interact with items, objects, and other characters within the game) and often times immersive virtual environments played via a personal computer or game-specific console. Learners are able to go through the training on their own time and without the aid of an instructor, but still receive the information they need to know in an effective manner, making them a less expensive training tool compared to large-scale virtual trainers.

Despite the overt differences, games and simulations also share a number of similarities, allowing researchers to draw comparisons between the two. For instance, both commonly use virtual representations projected onto some type of screen. Both will also utilize scenario-based exercises for training or learning purposes. Users typically interact with them by using a keyboard and mouse or appropriate controllers (e.g., flight sticks, steering wheels) and both offer a method of providing instructional guidance to a user with the ultimate goal of instilling new knowledge or skills.

The use of video games for learning is not a new concept. In fact, a wide range of instructional techniques in games used for training already exists. Some games, like Virtual Battle Space 2 (Bohemian Interactive, 2013), are highly immersive and realistic virtual environments used for military training, but lack true instruction within the game. These types of games are considered virtual sandbox trainers and are generally poor for training people of low prior knowledge due to a lack of guidance (Smeeton, Williams, Hodges, & Ward, 2005; de Jong, 2005). In contrast, games like *Pulse!!* (Breakaway Ltd., 2012) also provide a highly realistic virtual environment in which medical students practice their classroom knowledge within a virtual world. The game also includes embedded instruction from a typical health care curriculum into game play. These types of games provide guidance to the learner as they play, which aids in the learning process.

GBT also allows for individuals to "reenact a precise set of circumstances multiple times, exploring the consequences of different actions" (Trybus, 2012, para. 10). This characteristic can help reduce training costs over time (Clark, Nguyen, & Sweller, 2006) and, if developed properly, potentially improves the conceptual understanding of what is being trained (Atkinson & Renkl, 2007; Renkl, Atkinson, & Große, 2004). In order to accomplish this, the system must provide trainees with an accurate presentation of instructional information in real-time, experiences similar to those they may face in real-life, and effectively aid in both knowledge and conceptual development for the material.

In order to provide criteria that is more refined for instructional guidance in GBT, research needs to focus on how current theories or concepts for training and learning extend to GBT instructional design within interactive virtual environments. In fact, there are a number of

theoretical factors involved when approaching video games from a training perspective. Training

involves learning on the behalf of the trainee. One aspect of the stand-alone approach to GBT is

that it lacks the presence of an instructor. This lack of guidance means that some form of built-in

guidance is necessary for proper learning to take place. Guided approaches to learning

consistently outperform free-play or discovery approaches, largely because guiding learners frees

up valuable cognitive resources (Kirschner, Sweller, & Clark, 2006), particularly those needed

when processing and learning new information (de Jong, 2005). However, there is a lack of

substantive research exploring effective means of guiding learning or training in GBT.

Additionally, the driving force behind video games is a largely interactive and

multimedia-based experience. In terms of learning, the cognitive theory of multimedia learning

(CTML) is an appropriate theoretical basis on which to examine GBT. CTML explains how

people learn from multimedia presentations, or a combination of pictures and words (Mayer,

Bove, Bryman, Mars, & Tapangco, 1996; Mayer, 2009). Not only does it provide a well-

established model of how people learn from multimedia, it provides guidelines and principles for

developing these types of instructional presentations. Although not widely researched in

interactive GBT, CTML can provide a starting point for designing instructional guidance within

game-based multimedia approaches to learning.

Current Research on GBT

Research exists that supports the use of games for training (e.g., Mayer & Johnson, 2010;

Dickey, 2006; Dickey 2011; Leemkuil & de Jong, 2011). However, other research also exists

that fails to find significant benefits for using video games as stand-alone training devices (e.g.,

Derouin-Jessen, 2008; Lee et al., 2012). Although there are gaps in the research surrounding

6

certain aspects of GBT, positive findings from the existing research shed some light on the prospects of how to best utilize GBT, while negative or indifferent findings help uncover some potential areas where more research is needed.

Inconsistencies in the Literature

The different and inconsistent approaches to GBT research and implementation may be the reason why there is some disagreement about its effectiveness in the literature. Research has often shown that GBT is equally effective, if not better than, traditional classroom training approaches (Gega, Norman, & Marks, 2007; Vernadakis, Gioftsidou, Antoniou, Ioannidis, & Giannousi, 2012), which typically consist of using books and lectures as a teaching medium. For example, Vernadakis et al. (2012) compared physical body balance training using either a traditional approach (i.e., trampolines and balance boards) or a game-based approach (i.e., Nintendo Wii balance board and the Wii Fit Plus game). They reported that both groups significantly improved on measures of balancing ability. They claimed their findings supported the overall notion that a game-based version of the training was just as effective at improving performance as traditional training.

Similarly, Cheng & Annetta (2012) looked at how well a video game, designed to teach middle school students about the basic principles of neuroscience and the effects of drugs on the brain, increased the knowledge level of the students after the lesson. They found that students were able to learn significantly more information after using the game versus a non-game approach.

Expanding on that, research has also reported that GBT is effective, but only as a training supplement to other, more traditional, forms of instruction. A review by Sitzmann (2011)

reported that there might be a bias in the literature towards games that lead to positive training, stating that much of the GBT literature claims to test purely game-based approaches to training but actually include some additional, non-game form of instruction as well. She reports that games only seem to add real instructional value when used as a supplement to traditional forms of instruction.

However, other researchers have reported that GBT is not as effective at training specific tasks meant to transfer to other real-world environments or applications. Lee et al. (2012) manipulated whether or not participants received a type of hybrid part-whole task training or simple practice training on a game meant to teach better cognitive strategies for learning. They found that their test condition led to better performance, but only in the game. Neither type of training led to increases in cognitive performance on other transfer tasks, which was the goal of the training.

Given these examples, it seems as though GBT may only be partially effective at training individuals. However, the problems that plague GBT research are also apparent here: each approach utilizes GBT in a different fashion. No instructional standards exist for GBT because researchers and practitioners are manipulating different things and supplementing instruction in different ways. Therefore, attempting to extract foundational-level guidelines for designing GBT instruction from these studies may not lead to consistent results across experimentation. Research needs to focus on how and when to provide instruction based on how people actually learn from gaming media.

Guided Learning

In the traditional sense, learning occurs when someone unfamiliar with something receives new information or skills from an instructor or teacher. The teacher-student relationship is present throughout training and learning literature. Research has examined how levels of instructor training affect student competency (Deal, Bennet, Mohr, & Hwang, 2011), how instructor praise or criticism affects student stress levels while learning (Krahenbuhl, 1981), and the general interactions between teachers and their roles in the classroom with students and their responsibilities (Cantor, 1946). The teacher-student research domain stretches decades and it is obvious that this relationship is an important part of enabling the learning process. It may be important for GBT developers to understand and attempt to model this type of relationship as best they can in GBT environments in order to maximize learning.

Throughout the literature on training and learning, a guided learning approach seems to appear frequently. This approach is focused on the concept that deeper and more meaningful learning takes place when learners are guided through the learning process (de Jong, 2005; Kalyuga, 2007; Leemkuil & de Jong, 2011; Moreno, 2009), and notes the drawbacks of pure discovery learning (Kirschner, Sweller, & Clark, 2006; Mayer, 2004). Discovery learning is process of giving a learner a problem or task to work through or complete without direct guidance from an instructor. The idea behind discovery learning is that when given the proper tools or materials, learners will create a solution to the problem on their own. This, in turn, helps them develop better mental models for the task or problem, rather than being shown or taught how to perform the task (Bruner, 1961; Wu et al., 2011). However, there is an increased risk that learners will develop incorrect mental models of the material via this method of learning and

9

little research exists that supports the effectiveness of pure discovery learning (Kirschner, Sweller, & Clark, 2006). Guiding people through the learning process is considered by many as the most effective way to teach or train individuals. Therefore, a guided learning approach may be most appropriate for GBT design.

Guided learning is based on a cognitive centered approach for learning (Vogel-Walcutt et al., 2011; Kersh, 1962; Smeeton, Williams, Hodges, & Ward, 2005). The underlying principle of guided learning is that providing instructional guidance during learning or training promotes better learning by lowering cognitive load and freeing up cognitive resources for processing new information, which is essential for learning to take place (Vogel-Walcutt et al., 2011). This guidance is highly important as people may not form meaningful or correct connections between information on their own or without proper instructional interventions (i.e., form correct concepts or schemas for the material). This results in potentially improper application of the material and rising costs associated with mistakes and retraining. Part of this argument stems from the idea that the lack of guidance leads to massive amounts of processing required of the learner, which overly taxes cognitive resources and does not allow proper processing of new information to take place. Here, guidance can consist of real-time feedback, instructional interventions, detailed scaffolding, or procedural walkthroughs. In any case, the purpose of guidance is to lower the cognitive demands placed on the learner as they progress through their learning activity by providing some form of explanation, rationale, or detailed information that describes the material, concepts, or procedures in relation to one another. This allows for deeper learning to occur.

Research examining how guided learning affects knowledge acquisition has provided a foundation for its implementation. For example, Smeeton, Williams, Hodges, and Ward (2005) looked at the effectiveness of various instructional techniques to aid in athletic anticipatory skill development. Their findings indicated that trainees given explicit or guided instruction improved performance at faster rates than other non-guided forms of instruction.

Expanding Guidance in GBT

Guiding the learning process leads to more effective and deeper learning. Unfortunately, typical training in GBT is structured in a way that is similar to a discovery-based approach. This involves initially providing all the training information to the trainee in the very beginning of training (i.e., the first stage of training consists only of an informational session) and then allowing them to practice or demonstrate what they learned (i.e., the learner must recall all previous information in order to successfully complete the tasks in the gaming environment). Completing training in this fashion can overwhelm the trainee's cognitive resources and make it more difficult for him or her to recall or understand the information when the assessment is taken (Mayer & Moreno, 2002; Mayer, 2005). Therefore, it becomes prudent to ask whether this is the most effective way to train individuals.

By its nature, GBT is unique in that it is a highly practice-based, interactive, and stand-alone medium (Masson, Bub, & Lalonde, 2011). Based on guided learning instructional principles, supplementing GBT with integrated instruction should produce better learning outcomes than that of traditional training or GBT without supplemental material. For example, Cameron & Dwyer (2005) indicated that participants who trained with a computer-based instructional delivery system for educational purposes performed the best on delayed retention

tests when guided through the lesson with additional memory prompts. When applied correctly, a game-based instructional system that provides an appropriate level of instructional guidance will likely reduce the cognitive load of the participant (Duffy, Ng, & Ramakrishnan, 2004) and help them to achieve a high level of performance at a faster rate (Serge, Priest, Durlach & Johnson, 2013).

Games as Effective Training Systems

Using interactive games as a means to reinforce training material has resulted in better learning outcomes in educational settings than in traditional training settings (Thompson, Ford, & Webster, 2011). Interactive GBT is also associated with better critical thinking skills and knowledge application (Sotomayor, 2010), as well as better scores on measures comparing declarative knowledge, procedural knowledge, and retention than more traditional styles of training (Sitzmann, 2011). However, a problem exists when considering the fact that games are generally self-paced, individually based training. GBT is often times conducted with little or no instructor intervention during gameplay. Nevertheless, the majority of these studies utilize games as a training supplement, rather than a stand-alone, self-paced training system. It is possible to use instructional games as a means to train individuals without direct interaction with an instructor (Nicolescu et al., 2007; Weiner et al., 2011; Billings, 2012; Rhienmora, Haddawy, Suebnukarn, & Dailey, 2011), but few evidence-based principles exist on how to effectively embed guidance or training into the actual game-play so that the best possible learning outcomes occur. They tend only to state that the systems work (Guillen-Nieto & Aleson-Carbonell, 2012).

This lack of evidence may be attributed to the high amount of variability in GBT results. Questions regarding what type of information to present, when to present it, and in what format

12

the information should be delivered have received some attention from researchers. However, it is not possible to draw definitive conclusions from these reports. It has been strongly suggested that guiding learners through a training simulation or game can be much more beneficial than simply dropping them into the virtual environment without further instruction (i.e., free play) as to how to complete the task (i.e., guided instruction vs. discovery learning; Mayer, 2004).

It is also important to understand how different instructional methods affect how people learn the material. Is the goal of training to correctly answer questions on a knowledge test or to acquire the ability to perform the correct functions of a task when necessary? For the purposes of training complex tasks, the latter should prevail. However, existing findings are not yet complete enough to determine the most effective way of presenting training material to learners using interactive GBT, especially for training concepts and task procedures with real-world applications. Much of the current research provides an insight into how certain theories or concepts of training with GBT work. However, it also tends to focus on simpler types of training, resulting in a need for more research involving GBT for applied tasks and better conceptual understanding.

If given the proper attention, these approaches have the potential to help provide guidance for the use and development of video games for training. However, some of the things that make GBT so inviting for researchers and training developers also create some potential drawbacks for their implementation. GBT tasks do not take place in the real world. Actions or behaviors within them are removed from the real world or environment in which they naturally occur. This factor has been shown to sometimes lead to increased risk taking behavior within the game that would otherwise be impossible in real-life (Fischer, Kubitzki, Guter, & Frey, 2007).

This, in turn, may lead to difficulty applying skills learned in the gaming environment to the real world. Some of the benefits of using GBT are also affected by the feelings, attitudes, or abilities of each individual learner regarding games or computer-based training. Differences along these attributes can influence performance, learning outcomes, or engagement levels in games (Przybylski, Rigby, & Ryan, 2010; Orvis, Horn, & Belanich, 2009).

Despite the potential drawbacks and differing results, interest in games for training is still increasing and it is important that research provides adequate details to instructional designers regarding why and how implementing certain types of GBT is effective versus others. Without proper foundational-level research findings guiding training development, production of ineffective and inefficient training games may hinder ideal learning in many situations. Additionally, the cost of developing these types of training systems could become much higher if original designs do not succeed in fully training individuals.

It appears that there is still a continuous and growing utilization of GBT systems despite the lack of a clear consensus among researchers to guide the instructional design process. This is largely due to the sometimes-unfounded benefits perceived in games for training. Still, the fact remains that when well designed and appropriate for the situation, games have certain advantages over traditional lecture-based training that may also support their usage.

CHAPTER TWO: LITERATURE REVIEW

One of the goals of GBT is to provide a higher level of in-depth and complete training

and instill new knowledge in the learner without requiring the presence of a human instructor.

Since the literature lacks the necessary guidelines for developing these types of instructional

systems directly, a logical first step is to examine the fundamentals of how people learn, and then

apply those details to a gaming environment.

Games are largely driven by multimedia factors (i.e., they contain high levels of audio

and visual interactive stimuli). Given this fact, the question turns to how people learn from

multimedia. The cognitive theory of multimedia learning (CTML; Mayer, Bove, Bryman, Mars,

& Tapangco, 1996; Mayer, 2005) explains how people learn from multimedia presentations and

provides instructional design principles that may be applicable in GBT. CTML models the

learning process based on the ability of the learner to efficiently process information from such

presentations. Since video games consist of multimedia factors, CTML may provide a basis for

instructional design based on cognitive resources and human information processing in GBT

(Mayer 2001; Mayer 2005).

Cognitive Theory of Multimedia Learning

One of the central theories focusing on the effectiveness of learning from multimedia is

the Cognitive Theory of Multimedia Learning (CTML; Mayer 2001; 2009). The underlying

principle of CTML is that people are able to process a very limited amount of information at any

given moment. Therefore, the most effective learning occurs when the informational material

takes advantage of the multi-channeled processing capability of working memory (WM). This is

accomplished using multimedia presentations. Multimedia presentations consist of words (e.g.,

spoken or printed text) and pictures (e.g., illustrations, photos, animations, or videos; Mayer,

2005). See Figure 1 for a graphical representation of how CTML explains the learning process in

WM.
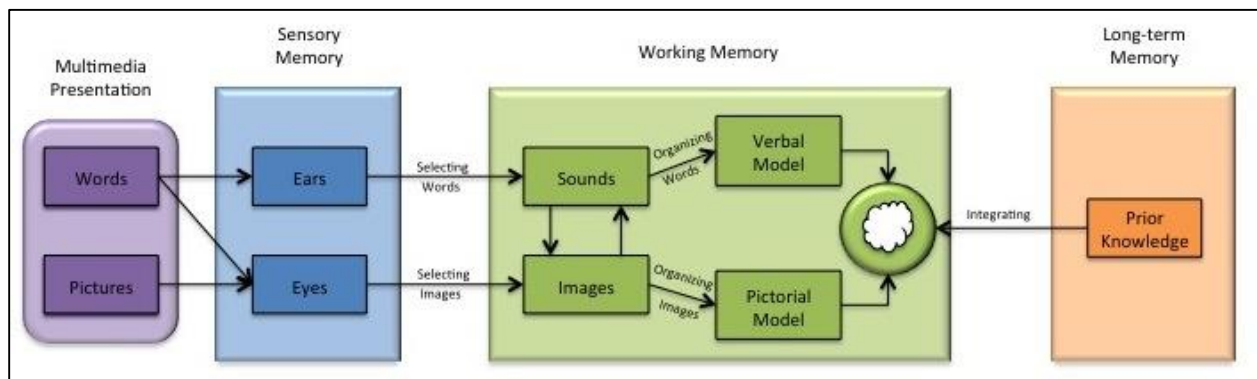
Figure 1. The Cognitive Theory of Multimedia Learning, adapted from Clark & Mayer (2008).

According to CTML, learning begins when a person selects relevant words and images

from a multimedia presentation. Next, the selected information is organized into coherent verbal

and pictorial representations in WM. Finally, the verbal and pictorial representations are

integrated with themselves and with prior knowledge in long-term memory (Clark & Mayer,

2008). This results in an understanding of the material and the creation of new knowledge.

CTML works on a number of well-established assumptions regarding the cognitive

processes involved in learning. The first assumption, the dual-channel assumption, states that

people possess separate systems for processing visual and verbal information from the

environment. The basis for this assumption comes from Paivio's (1971; 2007) dual-coding

theory (Mayer & Moreno, 2002), which states that visual- (i.e., imagery or pictures; non-verbal)

and audio-based (i.e., language; verbal) information is processed in separate modality-specific cognitive subsystems in working memory. Each of these subsystems is specialized for processing one mode of information and has the ability to form associations for related information between channels.

The second assumption states that there is limited channel capacity in working memory. This means that each channel (i.e., visual and auditory) has a limited amount of information that it can process at any given time (Baddeley, 1992). Support for this assumption comes from classical research on working memory. Active processing of information takes place in working memory and people are typically only able to hold a few items in working memory at any given time (Mayer, 2001). Poorly designed instructional presentations lead to higher processing requirements and risk exceeding the effective capacity of working memory to process information, which can inhibit learning.

The third assumption states that learning is an active process taken on by the individual. Mayer (2001; 2009) states that humans, by their nature, actively try to process, organize, and integrate incoming information with their prior knowledge or experiences to make sense of things. This means that people actively try to make sense of the information they are receiving, rather than acting as a passive observer. The assumption of an active approach to processing information means that the learner is naturally willing to attempt to form connections and meaning from the information they receive (Mayer, 2001; Mayer, 2009).

The learning process in CTML works by lowering the cognitive demand of the material by taking advantage of both channels of processing through a multimedia presentation. According to Mayer (2005), there are three types of cognitive processing that a learner may

17

experience during the learning process due to the learning material's organization. The first type of cognitive processing is called essential processing (Mayer, 2009). Similar in context to intrinsic cognitive load (Chandler & Sweller, 1991; Sweller, 2011), this type of processing results from the inherent difficulty of the instructional material being learned. According to Mayer (2005), essential processing is the amount of cognitive processing required to understand the material and is related to the difficulty of the learning material (i.e., the task, information, system being taught, etc.) relative to the person receiving training.

In contrast, extraneous processing occurs as a result of irrelevant material or stimuli involved in the learning process. This refers to processing additional or unnecessary information unrelated to the actual instruction (Mayer, 2005). Extraneous processing is similar to extraneous cognitive load, explained by Chandler and Sweller (1991), in that increases in this type of cognitive load are caused by the actual design of the instructional material itself, not the difficulty of the information being learned. This type of cognitive processing can hinder learning because it requires more cognitive resources to focus on, process, and react to the material itself, which may not be directly related to the learning material. For example, if an animation is presented on a screen with descriptive captions written below, the additional visual scanning required between the two points (i.e., the distance between the picture and the words) potentially increases extraneous load (Mayer, 2009). Likewise, the act of interacting with the training system or game via a keyboard or controller may be an extraneous factor to those with lower experience with computer systems or games, particularly if interacting with these systems draws attention away from the learning material. Limiting the amount of extraneous processing is paramount for successful learning and training outcomes.

Finally, generative cognitive processing refers to resources used during the process of developing a deeper understanding of the material and integrating new information with older mental models (Mayer, 2009). This concept is similar to germane cognitive load (van Merrienboar & Sweller, 2005), which concerns the processing of new information into schemas in long-term memory. This type of processing is associated with organizing and integrating new information with previous knowledge and creating new and deeper knowledge so that the information can be used in the future and in other situations or applications (Mayer, 2009). Generative processing is most crucial for deeper learning to take place.

Many studies support the application of CTML in traditional educational settings. For example, when comparing multimedia presentations with traditional, classroom or lecture-based teaching methods, those given multimedia instruction tend to perform better on transfer tasks (Harskamp, Mayer, & Suhrer, 2007), as well as see significant improvements on exam performance (Sanchez & Garcia-Rodicio, 2008). Additionally, research examining learning effects between traditional lecture-based approaches and those incorporating CTML design principles have shown much faster rates and quality of learning from multimedia-based approaches (i.e., medical education, Issa et al., 2011). These results support the notion that using multimedia presentations helps learners acquire a deeper level of learning, which is a foundational component of CTML.

CTML provides a number of instructional design principles to apply to multimedia presentations for learning. Applying some of these principles to GBT design may help to provide a consistent basis for future research and application to GBT.

The Modality Principle

The underlying principle of CTML states that people learn better from a combination of corresponding words and pictures rather than just words alone (Mayer, 2009). Additionally, studies comparing the manipulation and style of multimedia presentations consistently find better support for combining voice/audio instruction and corresponding pictures rather than text instructions and corresponding pictures (Moreno & Mayer, 1999; Mayer, 2009). The reason for this is because of the increased working memory load that occurs when the material is heavily loaded on the visual channel, such as when an instructional presentation consists of both text and pictures (i.e., both are processed along the visual channel); this phenomenon is referred to as the modality principle (Mayer, 2001; Mayer 2005).

The modality principle in CTML states, "People learn better from animation and narration than from animation and on-screen text" (Mayer, 2001, p.134). As stated previously, Mayer (2001) has suggested that the visual channel in WM becomes overloaded when material is presented solely in a visual format (i.e., text and pictures, processed in the visual channel), leading to higher extraneous processing and lowering the ability of working memory to organize and integrate information, which also hinders generative processing. Research on this effect has shown that it exists over a wide range of educational settings and material (Mayer, 2008). A series of studies testing the modality principle consistently found that retention and transfer test scores were higher for those participants watching narrated presentations on lightning formation than when text was overlaid onto the same presentation, with large effect sizes (Median $d = .97$, Mayer, 2005; Mayer & Moreno, 1998; Moreno & Mayer, 1999). Additionally, research involving learning to play a type of educational computer game showed similar results, such that

participants receiving narration covering the procedures needed to successfully play the game performed better on subsequent transfer tests than those receiving on-screen text-based information (O'Neil et al., 2000; Moreno & Mayer, 2002). The modality effect has also been observed outside the lab and in the classroom setting and similar results have been reported with students performing better on learning metrics when given materials that adhere to this principle versus more heavily text-based materials (Harskamp, Mayer, & Suhre, 2007).

However, a large proportion of research on the modality principle has focused on educational or declarative types of knowledge. Little research exists that has examined the effects of this type of instructional manipulation in interactive GBT with real-time or embedded instruction for increasingly complex and realistic tasks. This is particularly alarming considering the wide-ranging shift in GBT that includes training of tasks or skills beyond the declarative knowledge scope. Some research examining modality effects in GBT for simulated activities have reported positive findings (Fiorella, Vogul-Walcutt, & Schatz, 2012), but much work is still needed in order to determine the best approach for training complex tasks in highly interactive, game-based environments.

The Temporal Contiguity Principle

In many circumstances, traditional methods of training involve separate sessions: learning the material and then applying what was learned. A question arises from this: Would embedded training, which combines the learning and practice sessions, be more effective than typical successive training, where corresponding words and images are presented separately? In CTML, Mayer (2001, 2008) has described this concept as the temporal contiguity principle. This principle states that people learn more deeply from a multimedia presentation when

corresponding images and narration are presented simultaneously rather than successively (Mayer, 2005). The word-based information and pictures used to explain or teach a concept, set of skills, or task are presented temporally close to one another, which allows them to be processed simultaneously. This approach helps provide clearer connections between information and better understanding of the material when used in conjunction with other principles of CTML (Mayer & Moreno, 2002).

The temporal contiguity principle in instructional design works by taking advantage of the dual-channel assumption of CTML. When words and pictures in a multimedia presentation are presented simultaneously, both channels of working memory are able to process information and form meaningful connection between presented information. This contributes to effective organizing and integrating of the new information (Mayer, 2001), and a number of studies exist in which positive effects are seen for simultaneous presentation versus successive presentation (Mayer, Moreno, Boire, & Vagge 1999; Mayer & Anderson 1992; Mayer 2001).

Similar lines of research looking at temporal contiguity effects for item recall provided some support for the application of this principle in aiding recall of information. When asked to recall items from a list, more accurate performance was observed for items that were grouped closely together temporally (Kahana, Howard, & Polyn, 2008). Additionally, when items are grouped together, better recall has been observed when those items have some form of semantic relationship between them, such as a hammer and nails, rather than items that do not (e.g., a lamp and grass clippings; Howard & Kahana, 2002). Furthermore, research has also shown that episodic recall, or memory of things occurring to an individual at a given point in time, is better

when the information being recalled occurs temporally close and is semantically related (SederBerg, Miller, Howard, & Kahana, 2010).

When items that are related to each other are presented simultaneously in an informative setting, stronger associations are created in memory for those items. The temporal contiguity principle explains why presenting training information in a simultaneously presented multimedia fashion can be beneficial. First, in CTML, multimedia instructions are presented in separate channels of WM simultaneously. If the presentation is designed so that extraneous load is low and promotes good levels of germane load, better schema development and actual learning will occur. Presenting information simultaneously, with word-based explanations and animations revealing functional qualities, aids the cognitive processes needed for deeper learning and understanding to occur and leads to better results from training.

Retention and Transfer in CTML

Research on CTML often includes measures of both retention and transfer. Retention deals with the ability to recall information learned at some point in time. This is tested with a declarative knowledge assessment after receiving instruction. However, some research has suggested that retention is only best suited for measurement of rote learning, or the ability of an individual to memorize information quickly (Harskamp, Mayer, & Suhre, 2007). On the other hand, transfer refers to the ability to apply what was learned in training to a real-life, non-training situation, or other applicable area (Saks & Burke, 2012; Mayer, 2002). For example, transfer may be measured by constructing a real-world performance measure after learning from an electronic source (i.e., learning how to perform CPR online, then being tested using a physical training mannequin). Put more simply, retention measures how well one remembers the

information from training, while transfer measures how well one is able to apply what was learned to another simulated or real-life situation.

Research examining the modality principle has found that those receiving a multimedia presentation with animation and narration tend to perform much better on both transfer and retention tests than those receiving animation and text presentations (Mayer, 2001; Mayer, 2005). CTML research exploring learning effects from the temporal contiguity principle has reported mixed results regarding performance on retention tests. Mayer (2001) explains that over multiple experiments, retention performance was not always better between the simultaneous-presentation group and the successive-presentation group. Mayer concluded that despite the simultaneous group being able to form deeper understanding of the material as seen through transfer scores, the successive group was able to listen to the presentation without the additional distraction of the animation, canceling out the potential learning effects for retention. While retention results may sometimes indicate mixed effects, simultaneous groups consistently perform better on transfer measures than successive groups, signifying that simultaneous presentation led to deeper learning (Mayer, 2001).

Applying CTML to Instructional Guidance in GBT

Despite the fact that research is paving the way for the application of CTML instructional design principles in educational settings, there is still a large gap in the research examining whether or not these same principles apply in the same fashion when instruction is embedded in a game-based training system. By embedding training material into an interactive game-based environment, trainees may acquire a better understanding of the material, developing deeper conceptual understanding of the material more effectively than simply playing the game by itself

and without instruction. Integrating CTML principles into GBT design and development should increase the effectiveness of these systems in general. Applying the modality principle, in terms of voice versus text presentations, and the temporal contiguity principles, in terms of combining information presentation within the game (i.e., simultaneous training) or separate from the game (i.e., successive training) was thought to provide a walkthrough-style approach to training. Simultaneous and voice-based presentation in CTML eliminates the additional demand successive and text-based presentation puts on processing structures in memory (Mayer, 2008; Mayer & Moreno, 2002), which may be more pronounced in GBT systems because of the interactive layer of the human-system interaction components.

As mentioned previously, research that has taken a CTML approach to training focuses mainly on declarative knowledge or educational based tasks (e.g., educating participants on how solar cells work, Mayer & DaPra, 2012; learning about lightning formation, Mayer & Chandler, 2001). Mayer's model of information processing (as seen in Figure 1, above) provides an accurate representation for how individuals process new information from multimedia presentations in a very static sense. This means that information is provided in a passive manner, such as a slideshow-style presentation, lacking the immersiveness and interactivity of a virtual or simulated environment found in some GBT systems. Often times, by their very nature, video games deliver information to the trainee in a multimodal fashion. However, very little research exists that applies these concepts to immersive GBT. Therefore, a central focus of this research was to determine how well Mayer's model of information processing applies to expectations when adding game-based interaction in the learning model, illustrated in Figure 2. It was thought that the theory's principles of instructional design for multimedia presentations are beneficial

regardless of additional factors included in training. On the other hand, it may be that adding the game-interaction factor fundamentally changes how the model works and, by extension, the overall effects of the instructional design principles.

<div align="center">Training for a Complex Task</div>

Another goal and benefit of GBT is to provide a safe and realistic environment to use new knowledge and practice the skills and/or abilities that are applicable to real life. When training a real-life task in a game-based environment, the task tends to be of much higher complexity than a purely lab-based environment is typically able to create. As such, the method of instructional guidance has been shown to have a large influence on both learning and performance of a complex task, particularly when the task or task environment is one of high workload or stress (Paas & Van Merriënboer, 1997; Keinan, Friedland, & Sarig-Naor, 1990; Leung, Yucel, & Duffy, 2010).
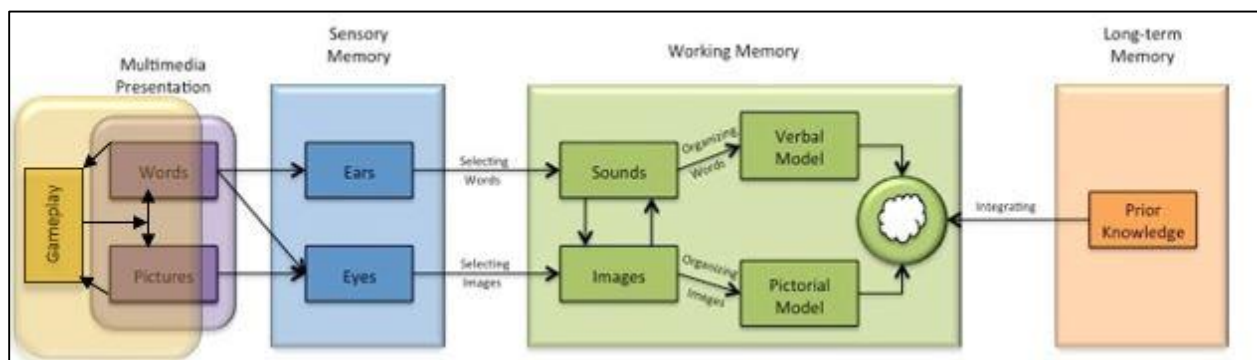
Figure 2. The Model of Information Processing Altered to Include Embedded Game-Based Instruction.

Performance and Workload

High task complexity or workload can severely affect a person's cognitive ability by decreasing their reaction time and performance on logical reasoning and spatial processing tasks (Harris, Ross, & Hancock, 2008). The increased load on a the cognitive system typically results from a sense of unfamiliarity from or a sense of personal threat within (i.e., danger, failure, etc.) an environment in which a person feels as though he or she lacks adequate knowledge to cope effectively (Hancock & Szalma, 2008). The increased load could also result from insufficient or ineffective training (Paas & Van Merriënboer, 1994). When an individual lacks the knowledge or skills to perform certain tasks in a high-stress environment, the sheer amount of incoming information can overload mental processing ability and lead to less efficient or incorrect decision-making and lower overall performance on a complex task (Litt, Reich, Maymin, & Shiv, 2011).

Fortunately, there are ways of mitigating the decrements in performance associated with tasks and environments with inherently high workload by creating training directed towards instilling better and deeper knowledge (Pass & Van Merriënboer, 1994), as well as providing a more realistic experience of the real-life conditions during the training process (Driskell & Johnston, 1998). These factors have been shown to help lower the cognitive pressures of the task or environment by better preparing the individual through training.

Task Complexity and Realistic Training

Higher complexity of a task is associated with poorer performance and higher mental workload (Leung, Yucel, & Duffy, 2010). This is especially true when the learner is required to apply knowledge or procedures within a dynamic or multi-task environment (Chen & Joyner,

27

2009). As mentioned previously, higher demands on cognitive processing generally have negative effects on learning (Paas & Van Merriënboer, 1994).

In addition, research has stated that familiarizing learners with the stressors or workload of the natural environment during training is an effective means of improving performance and resiliency in high stress environments (Driskell & Johnston, 1998; Stetz, Weiderhold, & Wildzunas, 2006). Stress training helped to prepare a trainee to perform under stressful and realistic circumstances and environments (Tichon & Wallis, 2010; Kluge & Burkolter, 2013; Driskell, Salas, Johnston, & Wollert, 2008). Creating realistic environmental stressors during simulation or game-based training has been found to help improve performance of complex tasks while under stress (Keinan, Friedland, & Sargi-Noar, 1990; Delahaij, van Dam, Gaillard, & Soeters, 2011).

Effective training may help alleviate some of the degradation in performance commonly found in tasks that have an inherently higher amount of complexity and workload (Friedland & Keinan, 1992; Hockey, Sauer, & Wastell, 2007). In these instances, certain types of training may help increase the ability to cope with complex and stressful environmental stimuli better than other training methods. These types of training focus on better preparation, deeper learning, and exposure to some of the stressors likely experienced during real-world performance of the task, which in turn leads to better performance of complex tasks. Research on utilizing this type of training with video games needs to be examined deeper, particularly when the skills being trained are highly complex and are required in high-stress or high-workload environments, such as those found in many military exercises and deployments.

Measuring Performance of Task Procedures in GBT

Much of the research examining videogame-based training has utilized the game as both the training tool and assessment measure. This is because it may not be feasible or advisable to assess training effectiveness or performance on certain tasks under true-to-life conditions without exposing those involved to potentially dangerous situations, as is the case with combat and some medically inclined training, for example. In order to test the effectiveness of a GBT program, researchers have sometimes increased the complexity of the task used for training in order to assess how well the learner actually learns the task and applies it under circumstances that are more naturalistic (Tichon & Wallis, 2010). Researchers often increase the complexity of a simulated task by including secondary tasks (e.g., question and answer tasks; Merat, Jamson, Lai, & Carsten, 2012), adding distracter stimuli (e.g., non-relevant targets in a target detection task; Elliot & Geisbrecht, 2010), or by increasing the inherent workload of the task (e.g., requiring higher precision and attention; Veltman & Gaillard, 1998). Doing so has led to increases on strain within WM and attention, which lowers the ability of a person to perform tasks at an effective level, but also allows for a more accurate real-world assessment.

However, the utilization of CTML for training knowledge and skills usable in highly complex environments is lacking. Therefore, it is important to examine how varying levels of complexity in the assessment of knowledge in GBT may lead to varying performance scores as a result of the style of training used. Delivering instructional presentations in a cognitively efficient manner that takes advantage of the processing capabilities of WM should lead to deeper knowledge (Mayer, 2005). Embedded training within the GBT environment provides additional exposure to common stressors associated with real-world performance of the task, which should

allow for an increase in knowledge and experience on how to cope with such stressors. This should lead to better performance of the task in applicable conditions.

The Current Study

Although there are studies that have reported positive findings with regard to GBT and learning, a number of questions involving the most effective and efficient ways of presenting instructional information to the trainee within gaming environments remain largely unanswered. This is evident throughout the mixed reports within the literature. Research needs to look at factors involving instructional guidance unique to GBT environments, particularly when the goal of training is to perform a complex task in a dynamic environment. These factors include the use of GBT as a stand-alone trainer without an instructor and factors influencing the presentation methods for self-paced GBT. Furthermore, other questions exist involving how manipulating the delivery or the presentation of information affects learning within an immersive game-based environment. This is particularly important when considering how people learn. Simply adding some form of instruction into virtual training environments without evidence of beneficial outcomes may result in ineffective training and higher costs associated with re-training. Research needs to take a foundational-level approach that accounts for both principles of human learning and how these may be affected through a game-based interaction.

Therefore, the goals of this dissertation were to empirically examine the effects of applying the modality and temporal contiguity principles of CTML within a GBT system. Games are a form of multimedia presentations. Games for training offer a variety of ways for providing instructional guidance within the game while a trainee is playing in real time. Much of the research on GBT has involved comparisons of different interventions on smaller-scale

knowledge assessments. These are not explicitly helpful when the goal of training is for skills and knowledge to transfer to a more realistic and potentially highly dynamic environment. This experiment examined which attributes of game-based instructional guidance, specifically the delivery of training information within an interactive game-based environment, were most effective for learning. Furthermore, the present research sought to determine how embedded versus upfront styles of instruction within gaming environments, modeled after the temporal contiguity principle, and the delivery modality of the learning material affected how well people learned a complex task via a game-based environment. In addition, this effort also sought to determine how well the CTML model of information processing applied to interactive GBT and how playing a game designed for training might change the magnitude of the expected effects for certain performance measures and fundamentally change the flow of information processing as laid out by CTML. Finally, measurements of individual differences, such as video gaming experience and spatial ability, were collected and used to determine potential effects on performance outcomes of training with interactive game-based environments.

Experimental Hypotheses

Based on previous research and theoretical review, a number of possible ways to present training information to a learner in a GBT environment were developed for this experiment. Learners need some form of instructional guidance for optimal learning to occur. Instruction also needs to account for the limitations of working memory and how game interactions may affect those limitations. The instructional methods were created by adapting the modality and temporal contiguity principles from CMTL to the design of training material for GBT. Research examining each of these principles has reported very specific and large effects on learning.

31

Therefore, the following hypotheses were created for the current research based on how each

principle would affect specific learning outcomes related to multimedia learning.

Hypothesis 1

It is hypothesized that performance on retention measures will reveal main effects for

both modality and temporal contiguity. This hypothesis is based on results from theoretical

research on the modality principle of CTML that reports consistent findings across multiple

studies and domains. Presenting a combination of voice and pictures is better for retention than

text and pictures (Moreno, 2006). Presenting information that takes advantage of the dual-

channel and limited channel capacity assumptions of WM explained by CTML leads to better

organization and integration of new information, and therefore deeper learning. This will be

evident on retention test scores between groups. Similar results are reported for the temporal

contiguity principle, stating that corresponding information presented simultaneously is better for

learning than the same information presented at different times (Mayer & Anderson 1992; Mayer

2001). Some research on the temporal contiguity effect in CTML finds little or no effects for

retention between manipulations. However, the present effort explores the effects of these

manipulations when incorporated into GBT, which may provide opportunities for deeper

conceptual connections to form due to the ability to practice what is being learned in real-time.

Therefore, three specific predictions were prepared to examine this hypothesis.

Prediction 1

The first prediction is that those receiving voice-based instruction, regardless of

presentation timing, will have better retention performance than those receiving text-based

instruction.

Prediction 2

The second prediction states that receiving instruction embedded (i.e., simultaneous presentation) into the gaming environment will lead to better performance on retention than upfront (i.e., successive presentation) instruction. Performance for the upfront instructional group may increase over pre-test measures, but will remain lower than the embedded group scores.

Prediction 3

The embedded instruction manipulation will have a stronger effect on performance, resulting in group-level differences on retention performance so that the embedded-voice and embedded-text groups perform better than the upfront-voice and upfront-text groups on retention tests. Modality will also aid learning, leading to the EV group performing better than the ET group and the UV group performing better than the UT group.

Hypothesis 2

The second hypothesis focuses on differences in transfer performance in GBT. It is hypothesized that main effects for both modality and temporal contiguity will be present on measures of transfer. Transfer is often considered a measure of deeper, conceptual learning because it involves applying the knowledge learned from a training session in another similar or real-world situation (Goldstein & Ford, 2002). Recent research has examined different styles of instruction and learning in games but has largely ignored design principles that may be relevant to embedded game-based instruction. From a multimedia learning perspective, both voice-based and embedded instruction should lead to deeper levels of learning by incorporating design principles that are beneficial to working memory. There are three predictions relating to the second hypothesis.

Prediction 1

The first prediction is that the voice delivery of instructional material will lead to deeper levels of learning as observed through transfer test performance. This will be evident as a main effect for modality.

Prediction 2

The second prediction states that a main effect for temporal contiguity will be observed in transfer performance. Specifically, embedded instructional methods will lead to better performance on the transfer test than upfront instruction methods.

Prediction 3

The third prediction is that embedded instruction will lead to higher overall performance than upfront instruction and differences will exist on modality within each group. More specifically, it is predicted that embedding the information within GBT, related to the temporal contiguity principle, will allow information and actions to be processed simultaneously, leading to better understanding of the material and more accurate replication of these procedures. Furthermore, embedded instruction within GBT provides an opportunity to observe and practice procedures related to the material in real-time. This should allow for learners to form strong conceptual connections for applying the information in a given situation. Deeper learning should manifest itself through performance on a written transfer test. Combining information delivery with practice should lead to both deeper learning (transfer) and have a stronger effect than modality across conditions. This means that embedded-voice instruction will have better performance than all other groups, with a linear performance relationship between the remaining

34

groups (i.e., embedded-text performing better than upfront-voice and upfront-voice performing better than upfront-text).

Hypothesis 3

The third hypothesis is that virtual performance of the trained task will be better when receiving training in both the embedded and voice-based instructional conditions. Main effects for both modality and temporal contiguity manipulations will indicate this result. A unique aspect to the current effort is the examination of a complex task requiring both declarative and procedural knowledge in order to reach proficiency. The practice-based approach, realized through embedded game-based instruction, provides an opportunity to learn-while-doing. This experience-based approach potentially lowers the processing requirements of WM and assists in the organization and integration of related information and procedures, resulting in deeper and more effective learning (Mane, Adams, & Donchin, 1989). This will be measured through two in-game assessments with differing levels of difficulty. Based on previous research and the reviewed theories, five specific predictions were made.

Predictions 1 & 2

Scores on the simple application test will also reveal better performance for both the voice-based and embedded training instructional designs. The training will have effects on performance in line with what is expected from CTML literature.

Predictions 3 & 4

The next two predictions for hypothesis 3 also state an observed main effect for both modality and temporal contiguity. Specifically, voice and embedded instruction will lead to better performance than text and upfront instruction.

Prediction 5

Group-level performance will indicate a stronger effect for embedded training than upfront training. Again, embedded training offers an opportunity to practice within a virtual environment that mimics the environment in which the task will actually be performed. Learning the task within the environment exposes the learner to the interactions, stress, and factors associated with performing the actual task, making them more ready and able to cope with such extraneous factors as they occur (Driskell & Johnston, 1998). However, text-based instruction may hinder this process by distracting the learner from what is occurring in the environment. Receiving all training information in the visual channel (i.e., text and pictures) requires single-channel processing in WM. This may compromise the capacity of the visual channel to process information effectively, which hinders proper organization and integration of information. This will result in significantly high scores on the assessment than when voice instruction is presented.

Hypothesis 4

Finally, it is hypothesized that instructional manipulations will have significant effects on ratings of subjective cognitive load and mental workload. CTML explains the learning process in terms of how instructional material affects working memory's ability to process incoming information (Mayer, 2008). Therefore, correctly applying the principles of CTML to multimedia-based instructional design should lead to lower feelings of mental workload and overall cognitive load throughout the training/instructional session. Two predictions are expected for this hypothesis.

Predictions 1 & 2

It is predicted that both modality and temporal contiguity will have significant effects on perceived cognitive load. Specifically, the voice-based and embedded instructional manipulations will result in lower ratings than upfront and text-based instructional manipulations.

Predictions 3 & 4

It is also predicted that both modality and temporal contiguity will have significant effects on perceived mental workload. Specifically, the voice-based and embedded instructional manipulations will result in lower ratings than upfront and text-based instructional manipulations.

Prediction 5

The embedded-voice instructional manipulation will report the lowest overall ratings on mental workload and cognitive load. Results will indicate an increasingly higher perceived mental workload and cognitive load between all instructional groups based on presentation style (i.e., EV < ET < UV < UT) during training.

CHAPTER THREE: METHODOLOGY

The current research aimed to empirically examine the effects of guided instructional techniques for GBT from a multimedia learning approach. One goal was to examine the applicability of two underlying and foundational instructional design principles of CTML within a GBT system. The experiment compared two presentational timing methods, upfront versus embedded, and two information delivery modalities, auditory versus visual. These factors were derived from the research and design principles of CTML.

Participants

A total of 128 participants were recruited from the University of Central Florida and surrounding area using the university's online participation recruitment tool. Participants included males and females with ages ranging from 18-43. All participants received compensation in the form of either monetary payment or college course credit. It was required that participants be fluent in written and spoken forms of English and have normal or corrected to normal vision. Participants were randomly assigned to one of four experimental conditions. All participants were treated in accordance with the ethical guidelines for the treatment of human subjects set forth by the American Psychological Association and the University of Central Florida Institutional Review Board.

Power Analysis

An a priori power analysis was conducted to determine the necessary sample size using the G*Power 3 computer program (Faul, Erdfelder, Buchner, & Lang, 2009). The following inputs were used for the power analysis: (1) medium estimated effect size of $f = .25$; (2) $\alpha = .05$;

(3) desired power level = .80; (4) Number of Groups = 4; (5) Numerator degrees of freedom = 1; and (6) number of covariates = 2. It was determined that 128 total participants are needed (32 per condition) to achieve a power level of approximately .80. This provided a critical F = 3.92.

Experimental Tasks

The experimental tasks were designed for a single participant to perform individually in one session. Each session included a period of instructional presentation, dependent on condition, practice in two training scenarios within the TC3 gaming environment, and performance assessments. Participants demonstrated their understanding of the instructional material within a self-paced, interactive game play session. Each training session differed slightly based on the condition (i.e., embedded instruction or upfront presentation; voice-based or text-based) in which each participant was assigned. The training material and actual game play were identical across all conditions.

Learning Objectives

Participants were required to demonstrate and apply knowledge in a computer game-based training environment for a combat lifesaver (CLS), a non-medical soldier who receives additional training on combat-relevant lifesaving medical procedures. Trainees learned essential information and procedures for providing medical assistance while in a combat zone. For the current experiment, proficiency of the CLS's training task included successful demonstration on two general domain areas of tactical combat casualty care: 1) basic knowledge and understanding of the roles and responsibilities of a CLS, and 2) following the correct procedures for addressing Care Under Fire and Tactical Field Care. Each of these skills contains specific

procedures that participants were required to learn for successful completion of each objective

(An overview of the four domain areas is present in Table 1).

Table 1

Descriptions and Responsibilities Involved in Tactical Combat Casualty Care

Domain Area	Description and Examples of Responsibilities

1. Information and Role of the CLS	1) Essential information necessary to fully understand and comprehend the CLS's role and responsibilities to the unit.
	   a. What is tactical combat casualty care (TCCC)?
	   b. What types of casualties occur on the battlefield?
	      i. How are those classified?
	   c. What are the responsibilities of the CLS?
	   d. What are the stages of care?

2. Care Under Fire and Tactical Field Care	2) First phase of TCCC when the CLS and casualty are under hostile fire.
	   a. Actions under fire
	   b. Actions before approaching the casualty
	   c. Providing care under fire
	   d. Checking casualty for responsiveness/consciousness
	   e. Controlling Hemorrhage
	   f. Moving to safety
	   g. CASEVAC

In order to demonstrate adequate knowledge, participants were required to learn how to

recognize specific injuries and the steps required to perform each skill properly within all domain

areas for combat casualty care.

Experimental Design

The present study was a 2x2 between-subjects design. The first independent variable,

presentation timing, was a between subjects variable with two levels (upfront and embedded).

The second independent variable, modality, was a between subjects variable with two levels

(auditory and visual). The main dependent variables included performance scores for retention,

conceptual problem solving transfer test scores, and in-game applied demonstration performance

scores, as well as subjective cognitive load and mental workload scores. Additionally, measures of spatial ability and gaming experience were identified as possible covariates based on the nature of the task and were collected through self-report metrics.

Experimental Covariates

Research has suggested that those with more experience with games perform better on tasks within gaming environments (Richardson, Powers, & Bousquet, 2011). Research has also reported that higher video game experience is associated with lower workload in game-based tasks (Neumann, 2007). This supports the idea that interaction within a gaming environment may create more load on cognitive systems when controlling, interacting, or maneuvering within the virtual environment is a novel task for someone. Therefore, video game experience was expected to act as a covariate in the GBT task and was an important consideration in the analysis.

Similarly, tasks requiring navigation within a virtual environment can be challenging for those with lower spatial ability. Higher levels of spatial ability have been shown to lead to better location-based learning and more accurate navigation within virtual environments (Chen & Joyner, 2009; Diaz & Sims, 2003). This may be due to the ability of the participant to know and understand their location in space quicker and more accurately than someone with lower spatial ability. Lower spatial ability leads to more time spent navigating within a virtual environment (Thomas & Wickens, 2006) and time spent attempting to familiarize oneself with their current location should lead to an increase in feelings of cognitive load and mental workload. Additionally, some studies have noted that spatial ability is a significant covariate of workload (Neumann, 2007). Based on past research, spatial ability was included as a covariate.

41

Experimental Conditions

Four instructional presentation conditions were created for this study. Each condition received training information, performed within the GBT environment, practiced what they learned through the training, and expressed what they had learned through knowledge tests and in-game performance. Two levels of presentation timing (embedded and upfront) and two levels of modality of instruction (visual/text and auditory) were between-subjects variables.

Timing of the Presentation

Timing of presentation was divided into two factors: upfront and embedded instruction. In this experiment, upfront training was defined along the lines of the traditional training approach; the initial part of the training session consisted solely of the informational presentation, while the latter session consisted of self-practice in the game without guidance. On the other hand, embedded presentation was defined in terms of an interactive GBT session; the presentation of learning material was provided in real-time as the trainee progressed through the game-based scenario designed for training. In other words, the trainee learned the material while he/she was practicing within the gaming environment. This is a slight modification of the original temporal contiguity principle. Rather than separating the words and pictures, which has been shown to consistently lead to negative effects on deeper learning, the instruction is now either separated from practice (i.e., gameplay) or embedded within practice. This manipulation was expected to extend the applicability of the temporal contiguity principle from CTML into GBT.

Modality of the Information

The modality of instruction was manipulated on two levels by altering how the multimedia presentation conveyed the information to the participants. Participants either received information via the auditory channel (i.e., information is spoken during the presentation) or via the visual channel (i.e., information is text-based and presented on the screen within the presentation or gaming environment).

Auditory instruction consisted of voice recordings that automatically played at certain points during the training, depending on the current progress and location of the participant's avatar within the virtual environment. Each recording corresponded to a specific step for completing the task or a bit of information necessary for continued progress within the game. This guidance continued until the gaming session was completed.

Visual instruction consisted of pieces of text-based dialogue boxes overlaid within the gaming environment represented on the computer screen. The dialogue boxes appeared at specific points during the training, depending on the current progress of the participant. Each dialogue box corresponded to a specific step for completing the task. This guidance continued until the gaming session was completed.

The information presented in both the auditory and visual modes of instruction was identical. Participants in the auditory condition heard the same bits of information as participants in the verbal condition read. All instructional information was developed from the Army Correspondence Course Program (IS0871) on the Combat Lifesaver Course (U.S. Army Medical Department Center and School, 2010) and the Handbook for Tactical Combat Casualty Care (Center for Army Lessons Learned, 2010).

Instructional Conditions

There were four instructional conditions in this experiment manipulated uniquely on both levels of the independent variables. Explanations of each of the experimental conditions are described below and listed in Table 2.

Table 2

Brief Description of Instructional Conditions

Condition	Description
Embedded-Voice (EV)	Instruction is delivered within the gaming environment via voice-over narration in real-time, relative to progress on the training task.
Embedded-Text (ET)	Instruction is delivered within the practice gaming environment via popup text-boxes in real-time, relative to progress on the training task.
Upfront-Voice (UV)	Instruction is delivered via a narrated multimedia presentation in a separate session prior to any exposure to the practice gaming environment. No guidance provided within the game.
Upfront-Text (UT)	Instruction is delivered via a text-based multimedia presentation in a separate session prior to any exposure to the practice gaming environment. No guidance provided within the game.

The embedded instructional group received training information in real-time as they progressed through the training. The instructional material corresponded to their current position within the game. This allowed an opportunity to practice new skills while they learned. Research suggests that this method of instruction can increase knowledge retention and transfer by

lowering the information processing demands of the learning material (Mayer 2009). The upfront instruction group experienced training in two parts: the first part consisted of a multimedia-based presentation containing of all of the training information for learning and performing the task; the second part consisted of practicing the skills presented during the first part in the game-based environment.

Each person in either the embedded or the upfront instructional group received instruction in either the verbal mode, in the form of pre-recorded auditory voice-overs, or the visual mode, in the form of on-screen text. The embedded voice (EV) group received the training information in the form of a voice-over that played back segments of the training information as the participant progressed through the game. The embedded text (ET) group received training information in the form of an on-screen text-based popup that provided training information as the participant progressed through the game. The upfront voice (UV) group received training information in the form of a PowerPoint-type presentation with narration, and then proceeded to the gaming environment to practice. The upfront text (UT) condition received training information in the form of a PowerPoint-type presentation with annotated information, and then proceeded to the gaming environment to practice.

Apparatus

Simulation Computer

All data collection was accomplished via a desktop computer. The system ran the gaming environment and the software necessary for instructional presentation and data collection.

TC3Sim Gaming Environment

The virtual gaming environment was called, "Tactical Combat Casualty Care Simulation" (TC3Sim), a proprietary, fully immersive computer-based game environment that provided a customizable virtual environment that was largely designed for training or experimentation purposes (ECS, 2007). It was developed as a means of incorporating combat lifesaving techniques into training for the U.S. Army soldiers taking the CLS course. A combat lifesaver is a nonmedical soldier trained to provide immediate lifesaving care to fellow squad or unit members in both combat and non-combat situations. Typically, one soldier in every squad is trained as a combat lifesaver as a means to bridge the gap between basic first aid taught to all soldiers and the highly specialized training given to combat medics. They are often the first responders to combat casualties (U.S. Army Medical Department Center and School, 2010). TC3Sim is a first-person shooter video game. In gaming terms, the first-person perspective means that the viewpoint projected onto the screen is from the "eyes" of the player's avatar, or in this case, the combat lifesaver's perspective.

TC3Sim provides an open environment in which a trainee can interact with other non-playable characters and learn the basic procedures for applying casualty care both in and outside of the combat area. For this experiment, TC3Sim was manipulated to resemble a gaming environment for learning by incorporating challenges and narratives into the training involving situations and relevant mission information. Participants operated in specific role within a larger unit and understood how well they were performing based on the status of their fellow soldiers, the environmental status, and the completion of specific goals.

Instructional Presentation Software

Training material was presented to participants via a PowerPoint presentation for the

upfront conditions, or a software modification that overlaid an informational window (for text-

based instruction; see Figure 3 for an example) or played an audio clip (for voice instruction)

within the game for the embedded conditions. The instructional presentation software provided

training information to the participant as they progressed through the game-based scenario

without user-required intervention or input.

Figure 3. Screenshot from TC3Sim with embedded-text instructional guidance. The
textbox on the side panel provides instruction to the learner in real-time.

Materials

Both paper-based and electronic materials were used to administer training and collect

data from participants. Measures included a demographics questionnaire, a video game

experience questionnaire, the Hegarty & Waller (2004) Object Perspective/Spatial Orientation

Test, the cognitive load questionnaire (Paas, 1992), the NASA TLX for workload (Hart &

Staveland, 1988). Performance assessments included pre and post knowledge tests for retention, conceptual transfer problem solving tests, and in-game performance assessments. Details of each are provided below.

Instructional Training Materials

The main training lesson consisted of either a PowerPoint presentation containing all training information or an interactive game-based tutorial containing all training information. Both presentations had identical material concerning the details of the CLS and their specific job functions. The material outlined the importance of the CLS, the proper procedures for applying TCCC under both care under fire and tactical field care situations, and some specific guidelines for treating two common types of injuries encountered during combat.

The first presentation type was a digital slideshow that explained the purpose and duties of the CLS, as well as the correct methods of performing some of the lifesaving skills necessary to become qualified as a CLS. Participants were able to control the pace at which the presentation flowed forward, but were unable to replay or go back to previous presentation slides. This prevented the upfront condition from receiving any additional benefits from re-viewing previous information, which was impossible for the embedded instruction group.

The second presentation type was embedded within the TC3Sim gaming environment. This presentation provided the same information as the slideshow presentation; however, material was in the form of a guided walk-through, or in-game tutorial. Participants simultaneously received instructional material and had the opportunity to practice what they learned within the gaming environment. Instructional material corresponded with participant progress through the game tutorial.

Demographics Questionnaire

The demographics questionnaire consisted of items pertaining to each participant's age, some personal preferences (e.g., handedness), prior medical training, prior military experience, and computer experience.

Video Game Experience Survey

The Video Game Experience (VGE) Survey was designed to measure how much exposure, familiarity, and experience participants have with playing video games. This survey consists of six items on a 5-point scale that focused specifically on video game experience and gaming preferences of the individual. Items include questions such as, "How often (approximately) do you currently play video games?" and "How would you rate your skill level for first-person/shooter video games?" This survey allowed for accountability of any variance observed as a result of potentially differing video game experience between participants. Results were calculated by adding the responses together to form an overall score.

Object Perspective/Spatial Orientation Test

The Object Perspective/Spatial Orientation Test (OPSOT) was developed by Kozhevnikov and Hegarty (2001) and revised by Hegarty and Waller (2004). The test measures a person's ability to perform mental rotations of their visual perspective in a space. The test has a high reliability rating and has been shown as an accurate measure of perspective taking skill. Scores from the OPSOT help determine if spatial ability has any significant effects on performance in a GBT environment. The test is scored by taking the absolute value of the

average degrees of deviation from correct for all 12 items (i.e., lower scores represent better performance). Any items unanswered are not included in the final score calculation.

Spatial ability is an important skill to consider when designing GBT systems involving immersive VEs because all environmental visualizations are accomplished through the computer screen, which requires players to mentally visualize other parts of the environment. The ability to accurately visualize different perspectives helps improve location tracking and waypoint finding within VEs (Waller, 2000; Diaz & Sims, 2003).

Cognitive Load Questionnaire

The Cognitive Load Questionnaire (CLQ; Paas, 1992) is a one-item questionnaire that asks an individual to gauge how much mental effort he or she perceived in completing a task (Paas, 1992; Kalyuga, Chandler, & Sweller, 1999). This questionnaire uses a 7-point Likert scale, ranging from very low mental effort or difficulty (1) to very high mental effort or difficulty (7).

NASA TLX

The NASA TLX, developed by Hart and Staveland (1988) is a subjective scale for rating perceived mental and physical workload for a task. It is comprised of six dimensions, measuring subjective ratings on each of the following: Mental demand, physical demand, temporal demand, performance, effort, and frustration. Each item is rated on a 20-point scale from "Very Low" to "Very High." Combining the responses to each item provides an overall workload score for each participant.

Learning performance was measured through a declarative knowledge retention test, a conceptual transfer test, and two practical application demonstrations within the gaming environment.

Declarative Knowledge Pre and Post Tests

The declarative knowledge pre and post-tests were used to measure retention of the material that was presented during training. The pre-test was used to measure an individual's prior knowledge on the subject matter and task before training takes place. The test consisted of multiple-choice questions relating to the specific nature of the task objectives and learning material. The post-test also consisted of multiple choice questions related to the subject matter and task, different from those on the pre-test. The post-test measured declarative knowledge after completion of the training session. The number of items correctly answered represented the score for an individual.

Conceptual Problem-Solving Transfer Test

The conceptual problem-solving transfer test was a free-response series of questions designed to measure an individual's ability to apply the knowledge learned during training to different hypothetical situations or scenarios. The test measured how well the different styles of instructional guidance enabled deeper learning of the training material. Scores were calculated based on the ability of the individual to correctly identify very specific rules and procedures. The number of correctly identified rules and procedures for a given scenario/situation constituted the total score.

Practical Application/Demonstration

The practical application/demonstration measure was based on the manipulation of combat environmental realism and consisted of two in-game scenarios designed to provide an opportunity for participants to apply the training information and their knowledge in a more realistic setting. These scenarios are similar, but differ in the level of environmental realism. The scenarios were designed in a way that required participants to apply all of the knowledge they gained during training in a more realistic and consequential environment than those observed during training.

The complex application test (CAT) is a virtual representation of a combat area designed to mimic more realistic environmental stressors and conditions likely encountered by a CLS on the battlefield (e.g., under enemy fire, multiple casualties, unknown terrain, etc.). Environmental complexity was increased by including factors typically associated with combat environments: hostile presence, sustaining enemy fire, and friendly soldiers sustaining casualties simultaneously. Since participants took on the role of the CLS in the game, the objective of the scenario was to perform a routine security sweep of a designated area and react accordingly to hostile presence if encountered.

The simple application test (SAT) takes place in the same virtual combat area as the CAT, except that it is designed without the inclusion of additional combat environmental stressors (i.e., no hostile presence or fire, one casualty requiring attention at a given time).

The differences in in-game complexity for the assessment scenarios was designed to help determine differences in training effectiveness for transfer of a complex task based on the type of instructional guidance received.

Scores were based on the proper order and successful application of procedures for four (4) main tasks, and related sub-tasks, associated with the role and responsibility of the CLS. If procedures were completed in the proper order, full scores were given. Procedures completed out of order were marked and given half, one-quarter credit, or no credit depending on the magnitude of the misplacement of the procedure. Successful completion of the task included the following major tasks, each including a number of subtask elements:

1) Remembering and properly executing the primary and secondary objectives of the CLS.

   a. Follow/stay close to squad

   b. Return and suppress enemy fire

2) Addressing two casualties in a care-under-fire situation when it is safe to do so by suppressing hostile fire, if applicable.

   a. Attempt communication with casualties

   b. Request suppression fire from uninjured squad mates

3) Properly applying procedures to two casualties under tactical-field-care protocols.

   a. Treating a hemorrhage properly (five steps)

   b. Treating a chest wound properly (six steps)

4) Reporting to the commanding officer and ordering a MEDEVAC/CASEVAC for casualties.

Procedures

Participants were required to read and sign an informed consent before participation. They were given the opportunity to ask questions about the experiment during the consent process. Participants were randomly assigned to one of the four possible instructional conditions.

Next, they completed the demographics questionnaire, the VGE questionnaire, the knowledge pre-test, and the OPSOT.

After the initial set of questionnaires was completed, all participants learned how to operate the controls within the TC3 gaming environment (e.g., how to navigate, interact with game elements, etc.) using a game-based, built-in game control tutorial. The tutorial provided the participant with hands-on experience with the controls and a virtual environment in which to practice freely. An explanation of the basic controls needed for the experiment was provided by an embedded narration that tracked the progress of the participant through the tutorial, providing necessary information as they advanced through the scenario. Following this training, instructional sessions began. These sessions differed based on the experiment condition.

Upfront Presentation Condition

Those in the upfront conditions first viewed a multimedia presentation that contained the information and training material for performing the CLS medical skills and procedures. After viewing the presentation, participants completed individual training scenarios in TC3 designed to allow for practice of each new skill. After completing the training scenarios, participants then completed the NASA-TLX and the CLQ.

Embedded Presentation Condition

Those in the embedded condition began by completing individual training scenarios in TC3 designed to provide practice for each skill. These scenarios contained all training information within the game, thus making the game a multimedia presentation of the training information by providing instructional guidance to the participant in real time, as they progressed

54

through the scenario. After completing the training scenarios, participants completed the NASA-TLX and the CLQ.

All Conditions

Following the training sessions, all participants completed the CAT and SAT in-game scenarios. The order in which these scenarios are completed was randomized and counterbalanced to account for potential carryover effects. After both scenarios were completed, participants completed the written performance measures, consisting of the declarative knowledge retention test and the conceptual problem-solving transfer test. Finally, the experimenter debriefed each participant on the nature of the experiment and compensated the participant for his or her time.

CHAPTER FOUR: RESULTS

Data Collection and Analysis Plan

All data from questionnaires and written tests were collected from each participant. In-game application test measures were coded from in-game performance. This data was coded from screen-capture video playback of participants' mission performance.

All data was analyzed using SPSS 22 and subjected to a series of statistical analyses to test the effects of different instructional presentation methods within GBT on measures of learning. An alpha level of .05 was used for all analyses, unless otherwise noted. All data was examined for potential irregularities that could affect results of statistical analyses.

Of the 128 participants, 67 were female and 61 were male. Participants had an average age of 20.73 years ($SD = 4.01$). Participants who had worked in the medical field (i.e., EMTs, nurses, etc.) or those with military experience were eliminated from analysis due to the likelihood that they would have some level of prior knowledge or experience that would artificially inflate their scores on the combat-related medical task being taught during the experimental session. A data screen was conducted to identify any abnormalities resulting from data entry or extreme outliers. Significant outliers can cause wide fluctuations in mean scores and inflate the standard deviations, which potentially bias the model on which we are trying to fit the data (Field, 2005; Field & Hole, 2003). No significant outliers or data entry errors were detected on performance measures.

Next, normality was checked using the Kolmogorov-Smirnov (K-S) test for normal distributions. Results of the normality tests revealed that some of the results for experimental measures deviated significantly from normal on some of the measures (See Table 3). However,

data from larger sample sizes are regularly found to be significantly different than normal (Field, 2005; Pallant, 2007). In these cases, it may still be appropriate to use parametric tests (e.g., *F*-test, ANOVA, ANCOVA) as long as the sample size is sufficiently large (Schmider, Ziegler, Danay, Beyer, & Buhner, 2010; Pallant, 2007).

Table 3

Results of Kolmogorov-Smirnov Tests for Normality on DVs and CVs

Variable	*K-S* statistic	skew	kurtosis	*p*
VGE	.163	.745	-.278	< .001*
Spatial Ability	.185	1.20	.478	< .001*
Retention Test	.097	.156	-.540	.005*
Transfer Test	.053	-.012	-.548	> .200
CAT	.061	.154	-.736	> .200
SAT	.123	.284	-.382	< .001*

Note. Significance measured at .05

Next, the two covariates (CVs), spatial ability and VGE, were examined. As a general rule of thumb, CVs should have a ± 0.3 correlation with the outcome variable of interest in order to contribute to the results in a meaningful way (Mayers, 2013). VGE was significantly correlated with all of the performance measures; the correlations were generally low for retention and the simple application test but higher for the complex application test. Spatial ability was significantly correlated with retention test scores, the complex application test scores, and the simple application test scores. Neither CV showed a significant correlation with the transfer test scores.

Neither of the CVs were both significantly correlated at or above this ± 0.3 correlation

cutoff with any of the performance measures. However, using multiple CVs in an analysis also

lowers the degrees of freedom, resulting in a loss of statistical power and increasing the

likelihood of committing a Type 2 error. Therefore, it was beneficial to use only one CV to avoid

any unnecessary loss of power. Additionally, VGE was considered a better predictor of

performance on the CAT, as the CAT took place within the virtual game environment. See Table

4 for these correlation values.

Table 4

Correlations between CVs and DVs

Measure	1	2	3	4	5	6
1. VGE	--					
2. Spatial Ability	-.14	--				
3. Retention Test	.16	-.41**	--			
4. Transfer Test	.15	-.15	.21*	--		
5. CAT	.36**	-.28**	.19*	.20*	--	
6. SAT	.19*	-.31**	.29*	.12	.45**	--

Note. *p <.05; ** p < .001

Additional assumptions for the use of covariates in an analysis are that the CV and

treatment effect are independent from each other (i.e., there are no effects on the CV variable

across experimental groups) and that the CV meet the homogeneity of regression slopes

assumption (Table 5). Analysis revealed no significant effects across experimental conditions on

either of the CVs. Spatial ability was found to deviate significantly from normal. As mentioned

above, parametric tests are typically considered robust against violations of normality with larger sample sizes. Additionally, the distributions of variances did not significantly differ between groups. Therefore, spatial ability remained in the analyses.

Hypotheses Testing

A series of analysis of variance (ANOVA) and analysis of covariance (ANCOVA) tests were used to compare differences between the training groups and performance on each of the four learning measures. The two covariates, VGE and Spatial Ability, were used to account for additional variance in the outcome scores where appropriate. The ANCOVA test allows testing of the main effects, interaction effects, and planned comparison contrasts of the results on each of the performance measures while accounting for differences in scores due to varying levels of the CV. The following sections report these results on each performance measure collected.

Hypothesis 1: Retention Test Performance

The first set of hypotheses stated that modality and temporal contiguity effects would be significant on the retention post-test score. This hypothesis was broken down into two predictions, indicating higher voice and embedded instructional condition scores on the retention test across manipulations. These are presented in detail below.

Table 5

ANOVA Results for tests of Independence (TOI) and Homogeneity of Regression (HOR) Slopes Assumptions for Covariates

	df	F	η_p^2	p
VGE TOI				
Modality	1(124)	.217	.002	.642
Temporal Contiguity	1(124)	.060	.000	.807
Modality*Temporal	1(124)	.285	.002	.594
Spatial Ability TOI				
Modality	1(124)	2.358	.019	.127
Temporal Contiguity	1(124)	.206	.002	.651
Modality*Temporal	1(124)	2.374	.019	.126
Spatial Ability HOR Test				
Retention	3(121)	.290	.007	.833
SAT	3(121)	.513	.013	.674
VGE HOR Test				
CAT	3(121)	1.850	.044	.142

Note. Sig. measured to p < .05. HOR test results only include those that were included in the final analysis.

The knowledge pre-test was administered before training to ensure that there were no group differences on knowledge for the task prior to the experimentation (See Table 6 for means and standard deviations for the pre- and post-test measures). An ANOVA was run to check this assumption. The test revealed that no significant differences existed between experimental groups, $F(3,124) = .684$, $p = .564$, for the pre-test. Additionally, pre-test scores were compared to post-test scores to ensure that some level of learning occurred due to the training sessions. A t-

test revealed that post-test scores ($M = 11.24$, $SD = 2.87$) were significantly higher than pre-test scores ($M = 6.16$, $SD = 1.85$; $t(128) = -18.85$, $p < .001$, $\eta_p^2 = .16$). This indicates that receiving some form of training had a positive effect on learning as measured by the retention test. Individual t-tests were conducted to determine if all groups improved significantly from their pre-test scores. Results indicated that this was indeed the case. Refer to Table 6 for results for these analyses.

To test the predictions made by H1, an ANCOVA on retention test scores was conducted to examine the differences between the instructional manipulations using modality and temporal contiguity as the IVs and spatial ability as the CV. Three specific predictions were made to examine and explain these relationships.

Table 6

Overall Means and Standard Deviations for Pre-Test Performance Between Experimental Conditions

Condition	Pre-Test M (SD)	Post-Test (Retention) M (SD)	df	t
EV (N=34)	6.12 (1.55)	10.76 (2.44)	33	-10.36*
ET (N=31)	6.13 (1.91)	10.10 (2.80)	30	-7.38*
UV (N=31)	5.87 (2.06)	12.32 (3.07)	30	-13.92*
UT (N=32)	6.53 (1.90)	11.81 (2.75)	31	-8.53*

Note. * p < .001

Results from the overall analysis revealed that spatial ability was a significant covariate, indicating that spatial ability was related to performance on the retention post-test, $F(1, 123) = 25.07$, $p < .001$, $\eta_p^2 = .169$, $r = -.41$. Better spatial ability scores were associated with higher performance on the retention test between instructional conditions (See Figure 4). After

controlling for spatial ability, a main effect for temporal contiguity was found. However, no

effects for modality were observed. Similarly, no interaction effects were detected. These results

are presented in detail below.
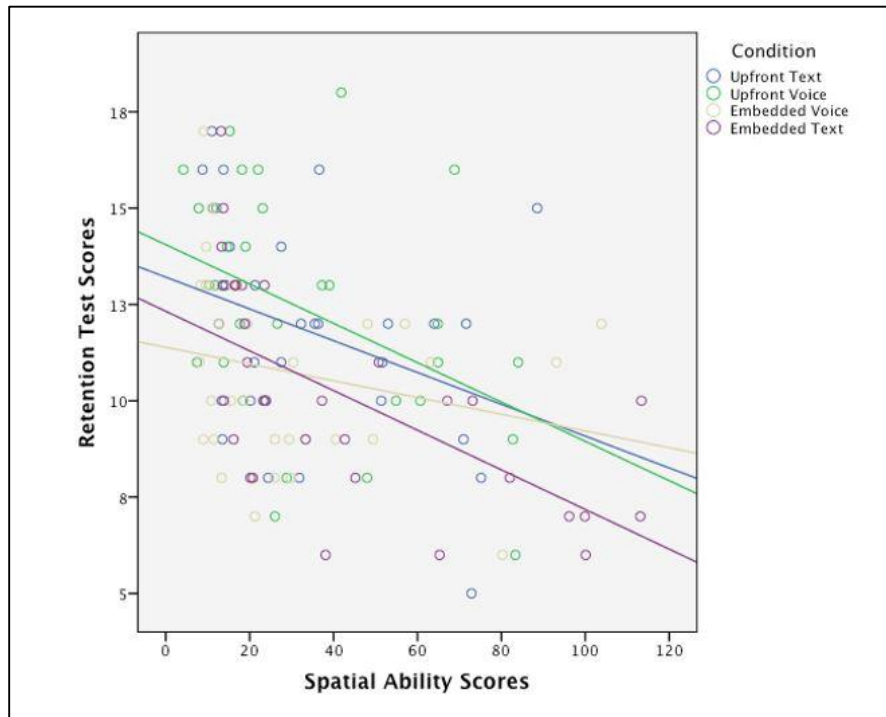
Figure 4. Linear relationship between Spatial Ability and Retention Performance

Prediction 1: Modality Effect on Retention

The first prediction for hypothesis one stated that there would be a main effect for the

modality manipulation and those receiving voice-based instruction would score higher on the

retention test than those receiving text-based instruction.

Results comparing voice instruction and text instruction did not indicate a main effect of

modality on performance of the retention test ($F(1, 123) = .383$, $p > .05$). Therefore, the first

prediction was not supported; no modality effect was observed between the voice ($M = 11.51$,

SD = 2.85) and text (*M* = 10.97, *SD* = 2.89) manipulations. Receiving voice-based or text-based instruction led to similar performance improvements on the retention test.

Prediction 2: Temporal Contiguity Effect on Retention

The second prediction for H1 stated that there would be a main effect of temporal contiguity on retention test performance. Specifically, those receiving embedded instruction would perform better on the retention test than those receiving upfront instruction. Analysis revealed a main effect for the temporal contiguity manipulation after controlling for the effects of spatial ability ($F(1, 123) = 11.896$, $p = .001$, $\eta_p^2 = .088$).

The effect was significant, however, results indicated an opposite effect than what was predicted; participants receiving upfront instruction (*M* = 12.06, *SD* = 2.90) performed significantly better than those receiving embedded instruction (*M* = 10.97, *SD* = 2.89; Figure 5). Participants who received the training information in a separate session (i.e., outside of the gaming environment) did better on the retention test by approximately 7% than embedded training group members. Therefore, while a significant effect was found, prediction 2 was not directly supported.

Prediction 3: Individual Group Performance on Retention

Based on theoretical review, it was predicted that timing of instruction (i.e., embedded or upfront) would have a greater overall effect on retention but delivery modality would help to offset some of the differences observed between temporal contiguity manipulations. The assumption was that receiving embedded instruction would be the most beneficial to performance, but receiving voice instruction would also help to alleviate the cognitive demands of training. This meant that the EV group would have the highest scores, followed by the ET

group, the ET group would perform better than the UV group, and the UT group would have the lowest scores on the retention test.
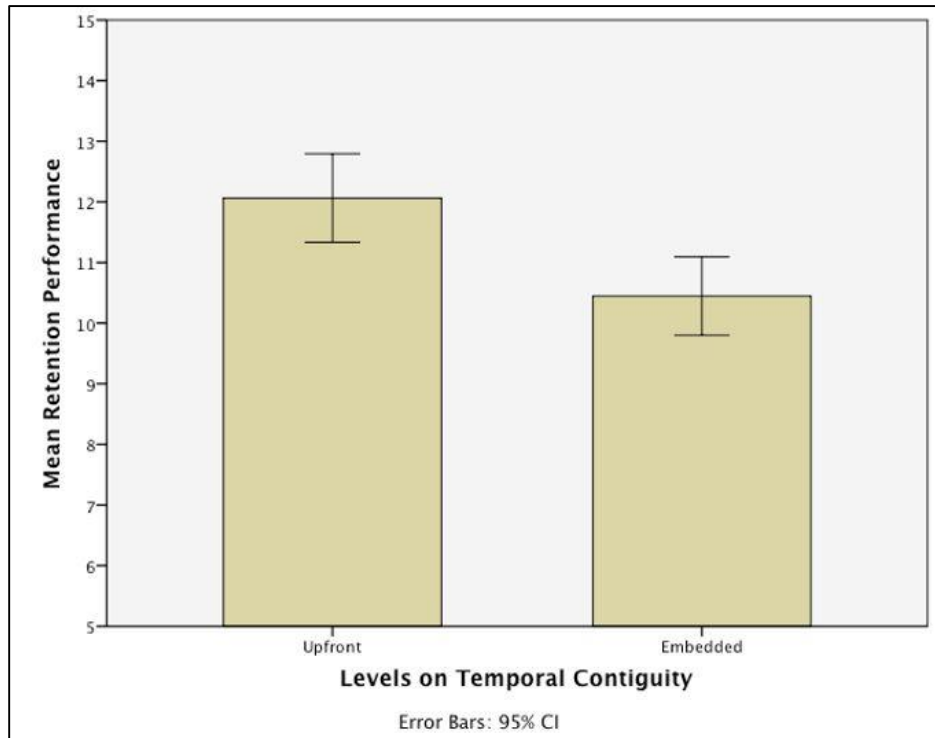
Figure 5. Mean differences between levels of temporal contiguity on the retention test

However, as presented above, the results indicated no modality effect and a reversed temporal contiguity effect with no interactions. Group-level analysis revealed a significant difference between groups on the retention test when accounting for spatial ability (F (3,123) = 4.16, p = .008, η_p^2 = .092). Table 7 shows results from planned comparisons between groups. The UV and UT conditions performed similarly to each other, while the UV group significantly outperformed both the EV and ET conditions. The EV and ET conditions also failed to perform significantly different from one another. Although the UT group comparisons alpha levels are below .05, Holm's sequential Bonferroni adjustments (Holm, 1979) changed the significance

thresholds to .0125 and .0167, respectively, for those comparisons to account for potential

family-wise error (Refer to Table 6 for group means).

In summary, those who received either type of upfront instruction performed better than

those receiving either type of embedded instruction, regardless of modality, but the UV condition

showed the best overall performance. Prediction 3 was also not supported.

Table 7

Planned Comparisons between Instructional Conditions on
Retention Test Scores

Condition	*F*	*df*	*p*
UT vs. UV	.643	1, 123	.424
UT vs. EV	4.102	1, 123	.045
UT vs. ET	4.180	1, 123	.043
UV vs. EV	7.953	1, 123	.006**
UV vs. ET	7.940	1, 123	.006*
EV vs. ET	.006	1, 123	.940

Note. Sig. at.0083** and .01*; Holm's bonferroni adj.

Hypothesis 2: Transfer Test Performance

The second group of hypotheses were concerned with the effects of modality and

temporal contiguity on the conceptual problem solving transfer test. Hypothesis 2 stated that

main effects would exist between modality and temporal contiguity on performance of the

transfer test, such that those participants receiving voice-based and/or embedded instruction

would perform better than those receiving text-based and/or upfront instruction. A factorial

ANOVA was used for this examination with modality and temporal contiguity as the fixed

factors and transfer tests scores as the DV. Neither of the CVs met the criteria for being included

in this analysis and were excluded. Three predictions were made in order to examine the

expected observed effects for transfer test performance. Descriptive statistics for group

performance on this analysis can be found in Table 8.

Table 8

Means and Standard Deviations for Main Effects and Individual Groups on the Transfer Test

Modality	Temporal Contiguity	*M*	*SD*	*N*
Voice	Upfront	8.84	2.71	31
	Embedded	9.64	3.25	34
	Total	9.26	3.01	65
Text	Upfront	7.26	2.89	32
	Embedded	8.01	3.01	31
	Total	7.63	2.95	63
Total	Upfront	8.04	2.89	63
	Embedded	8.86	3.22	65
	Total	8.46	3.02	128

Prediction 1: Modality Effect for Transfer Performance

The first prediction of H2 stated that a main effect for modality would exist on scores for

the conceptual problem solving transfer test. Specifically, it was assumed that individuals

receiving training information in the voice modality would perform better on the transfer test

than those in the text (visual) modality. Analysis revealed a significant effect for modality

($F(1,124) = 9.235$, $p = 0.003$, $\eta_p^2 = .069$). Receiving voice instruction led to participants

providing 1.6 correct steps, or details, more than text instruction on the transfer test (Figure 6).

This equates to an approximately 6.5% increase in performance. Therefore, prediction 1 for

hypothesis 2 was supported.
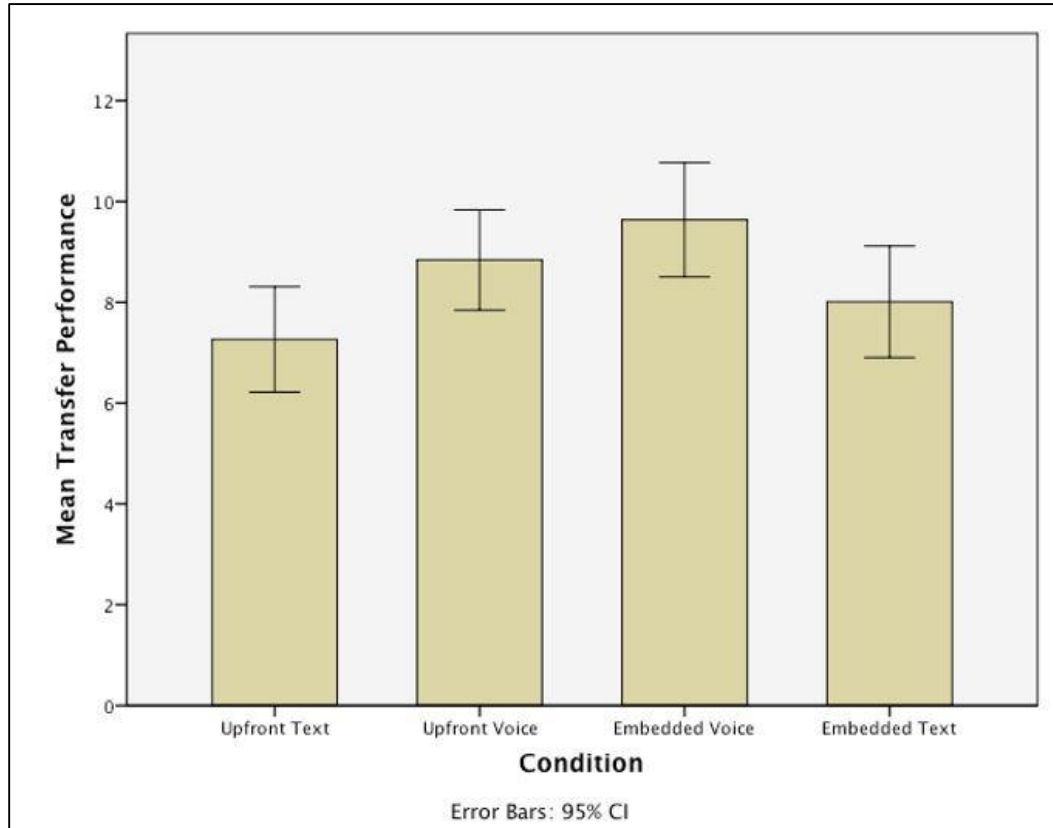
Figure 6. Mean transfer performance across instructional conditions

Prediction 2: Temporal Contiguity Effect for Transfer Performance

Prediction 2 for H2 stated that a main effect for the temporal contiguity manipulation

would also exist. Specifically, it was predicted that embedding training information within the

game-based training scenarios would lead to better conceptual understanding of the material, and

thus better transfer test performance, than providing training in an upfront session. Results did

not support this assumption, $F(1,124) = 2.139$, $p = 0.146$. Mean scores between groups on the

temporal contiguity manipulation indicated that the embedded training group ($M = 8.85$, $SD =$

3.22) performed similarly to the upfront training group ($M = 8.04$, $SD = 3.01$). Thus, prediction 2 was not supported.

Prediction 3: Individual Group Performance on Transfer

The third prediction for hypothesis 2 expected some specific group differences between conditions. Based on the theoretical underpinnings derived from CTML, it was predicted that the EV group would perform better than the ET group on the transfer test, followed by the UV and UT groups, respectively. The UV and UT groups would have lower overall performance but the UV group would perform better on the transfer measure than the UT group due to the fact that receiving voice-based instruction is supposed to lower the processing load of working memory.

The ANOVA revealed significant effects for condition (F (3,124) = 3.891, $p = 0.011$, η_p^2 = .086). Planned group comparisons on transfer test scores partially supported the group assumptions. Table 9 shows results of these comparisons. The EV group performed better than the UT group (partially supporting the prediction). However, all other comparisons failed to reach significance. Additionally, the EV group ($M = 9.63$, $SD = 3.25$) performed better than all other groups combined ($M = 7.92$, $SD = 2.89$; F (1,123) = 8.113, $p = 0.005$, η_p^2 = .062). Overall, prediction 3 was only partially supported.

Table 9

Planned Comparisons Between Instructional Conditions on Transfer Performance

| Condition | *M* | Mean Differences (Effect Size) | | | |
		1.	2.	3.	4.
1. EV	9.63	--			
2. ET	8.01	-1.628[+]	--		
3. UV	8.84	-.797	.757	--	
4. UT	7.26	-2.398* (.081)	-.745	-1.576[+]	--

Note. $p < .002$. Sig. value adjusted using Holm's sequential bonferroni adjustment for six tests. Effect sizes are reported in η_p^2. [+] Indicates sig. before Holm's correction.

Hypothesis 3: Application Test Performance

The third series of predictions involved performance on the practical application tests. The application tests were in-game assessments of the procedural execution of combat lifesaver's tasks. Participants completed two different scenarios designed to test their ability to perform the task, each scenario designed with differing levels of difficulty. Grading of the application tests consisted of reviewing screen captured video playback of in-game performance. Scoring was completed using standardized checklists; if a participant performed the correct procedure, in the correct order, they were given full credit. If they completed the procedure out of order, they were given half credit for the procedure. Inter-rater reliability was measured between two independent raters on the measures and indicated very high reliability on the CAT (Intraclass correlation [*ICC*] = .95, $p < .001$) and the SAT (*ICC* = .94, $p < .001$) scores.

The third hypothesis stated that those participants receiving training information in the embedded and voice groups would perform better on in-game assessment/application tests when compared to those in the upfront and text-based instructional groups.

A manipulation check was first conducted to determine whether the CAT was more difficult than the SAT. The scenarios were designed to be similar in content but differ on overall scenario complexity and environmental realism in order to increase the difficulty of performing the task procedures. A paired-samples t-test was conducted to determine whether the CAT was more difficult than the SAT. The results revealed that this was indeed the case, supporting prediction 1. Scores on the CAT ($M = 6.04$, $SD = 3.59$) were significantly lower than scores on the SAT ($M = 8.34$, $SD = 3.22$; $t(127) = 7.36$, $p < .001$; Figure 7).
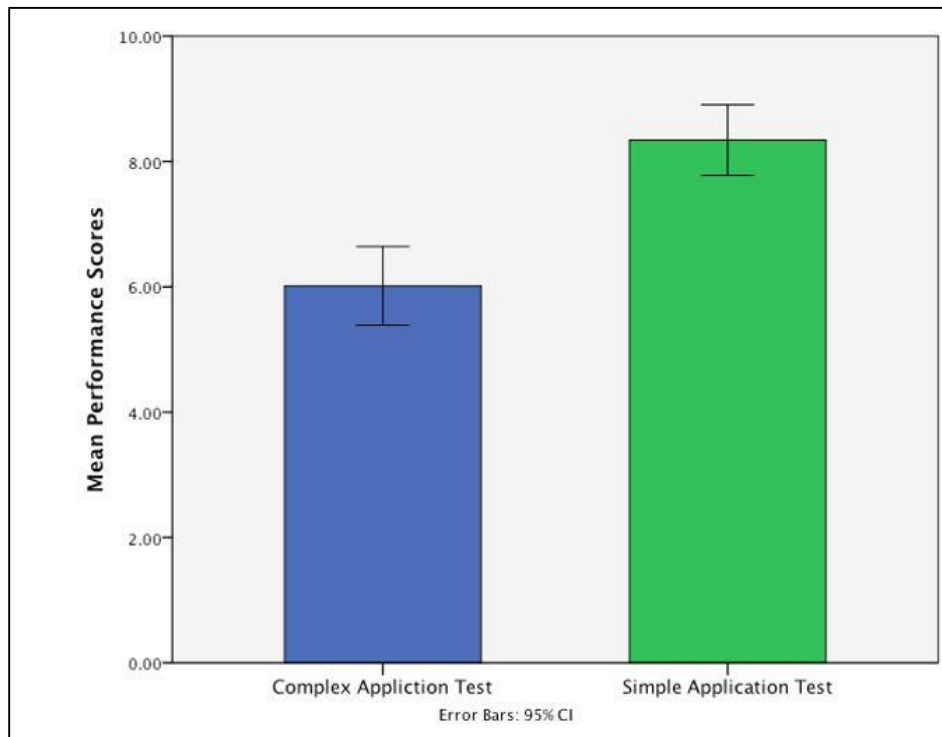
Figure 7. Mean performance differences between the CAT and SAT.

Predictions 1 & 2: Modality and Temporal Contiguity Effects for SAT scores

Predictions 1 and 2 stated that main effects for modality and temporal contiguity would exist on scores for the SAT. Specifically, the assumptions were that the voice-based and embedded instructional conditions would perform better on the SAT than the text-based and upfront groups. An ACNOVA was used to examine these predictions, with modality and temporal contiguity as the IVs, SAT score as the DV, and spatial ability as the CV. See Table 10 for the adjusted means for the application test scores. Results from the analysis did not support these predictions for the SAT (Modality: $F(1,123) = .166$, $p > .05$; Temporal Contiguity: $F(1,123) = .030$, $p > .05$). In addition, no interaction effects were observed either ($F (1, 23) = 0.391$, $p > .05$). Thus, both predictions 2 and 3 were not supported; scores on the SAT did not differ because of the presentation method.

Table 10

Adjusted Means for Main Effects and Individual Groups on the SAT

Modality	Temporal Contiguity	*M*	*N*
Voice	Upfront	8.323	31
	Embedded	8.574	34
	Total	8.448	65
Text	Upfront	8.444	32
	Embedded	8.001	31
	Total	8.222	63
Total	Upfront	8.383	63
	Embedded	8.287	65
	Total	8.334	128

Note. Means adjusted to the CV Spatial Ability (34.81)

Predictions 3 & 4: Modality and Temporal Contiguity Effects for CAT Scores

Predictions 3 and 4 stated that main effects for modality and temporal contiguity would exist on scores for the CAT. Again, the specific assumptions were that the voice-based and embedded instructional conditions would perform better on the CAT than the text-based and upfront groups, respectively. An ANCOVA was conducted to examine these predictions with modality and temporal contiguity as the IVs, CAT score as the DV, and VGE as the CV. VGE was a significant CV in the model (F (1, 123) = 19.497, $p < .001$, $\eta_p^2 = .137$, $r = .36$), indicating that prior experience with video games was positively related with scores on the CAT. Results did not support these predictions. Neither the modality manipulation (F (1, 123) = 2.242, $p > .05$) nor the temporal contiguity manipulation (F (1, 123) = 0.141, $p > .05$) revealed significant effects on CAT scores (Table 11 for adjusted means).

Table 11

Adjusted Means for Main Effects and Individual Groups on the CAT

Modality	Temporal Contiguity	*M*	*N*
Voice	Upfront	5.702	31
	Embedded	7.148	34
	Total	6.425	65
Text	Upfront	6.050	32
	Embedded	5.044	31
	Total	5.547	63
Total	Upfront	5.876	63
	Embedded	6.096	65
	Total	5.988	128

Note. Means adjusted to the CV VGE (13.29)

Prediction 5: Interaction on the CAT

A significant modality by temporal contiguity interaction was found, F (1,123) = 4.37, p = .039, η_p^2 = .034). Tests of simple effects indicated that scores on the CAT were different within the embedded training group; there was an effect of modality (F (1,123) = 6.54, p = .012, η_p^2 = .051; Figure 8). Modality affected the embedded instructional group differently than the upfront group. Voice instruction in embedded training (M = 7.15, SE = .568) led to better performance on the CAT than the embedded-text instruction (M = 5.04, SE = .595). Modality did not have an effect on the upfront instructional group. The differing effect of modality across the embedded training condition supports the prediction while the non-significant findings between the upfront conditions do not. Predictions were partially supported. Additional group level analyses revealed a non-significant effect for instructional condition on the CAT, not supporting predictions (F (3,123) = 2.308, p = .08).
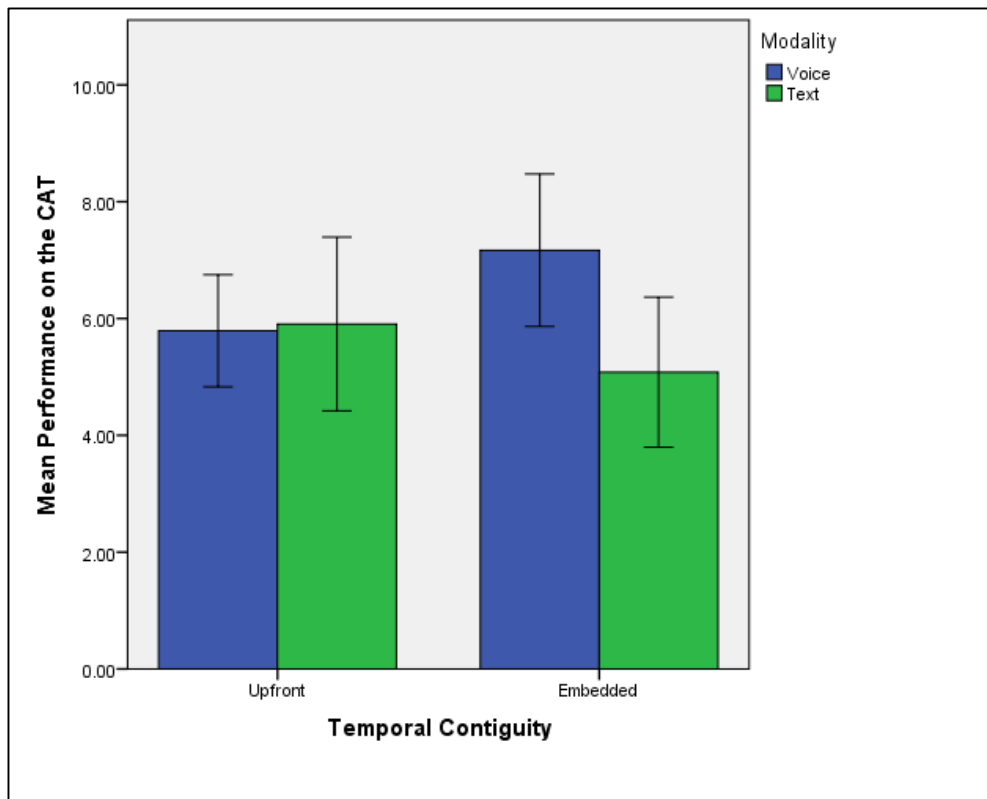
Figure 8. Simple main effects for embedded instruction along modality.

Hypothesis 4: Cognitive Load and Mental Workload

Cognitive load and mental workload measures were obtained after instructional

delivery/training sessions were completed in order to examine differences elicited from the style

of training presentation. It was assumed that spatial ability and VGE would be significant

covariates with both cognitive load and mental workload; those with higher VGE and better

spatial ability were expected to have more familiarity with video game interactions, leading to

lower feelings of cognitive load and mental workload experienced through gameplay and/or

instructional presentation. However, CV assumption checks revealed that the only suitable CV-

outcome relationship existed between VGE and scores on mental workload. Therefore, VGE was only used as a CV as part of the analysis for mental workload and instructional condition.

The fourth hypothesis stated that instructional conditions would lead to different scores on measures of cognitive load and mental workload for training. Two specific predictions were made to test these differences.

Predictions 1 & 2: Temporal Contiguity and Modality on Cognitive Load

It was predicted that main effects for receiving embedded and voice-based instruction would result in lower CLQ scores than receiving upfront and text-based instruction.

First, a one-way ANOVA was conducted to analyze CLQ scores between instructional manipulations. The test revealed a significant effect for modality ($F(1,122) = 5.002$, $p = .027$, $\eta_p^2 = .04$) but no effect for temporal contiguity was observed. Voice instruction ($M = 5.94$, $SD = 1.69$) led to lower ratings of cognitive load than text instruction ($M = 6.59$, $SD = 1.45$). These results partially supported the prediction.

Predictions 3 & 4: Temporal Contiguity and Modality on Mental Workload

Next, an ANCOVA was conducted on NASA-TLX scores using temporal contiguity and modality as the IVs and VGE as the CV. The results supported the assumption for a temporal contiguity effect, $F(1, 121) = 5.072$, $p = .02$, $\eta_p^2 = .04$. Overall, embedded instruction ($M = 44.08$, $SD = 21.01$) led to significantly lower scores on workload than the upfront instruction ($M = 52.67$, $SD = 20.79$). Results also revealed a main effect for modality ($F(1, 121) = 5.543$, $p = .02$, $\eta_p^2 = 0.044$). Voice-based instructional groups ($M = 43.79$, $SD = 19.32$) reported lower workload ratings than text-based instructional groups ($M = 52.68$, $SD = 20.38$). Predictions 3 and 4 were supported.

Prediction 5: Embedded-Voice Instruction on Cognitive Load and Mental Workload

The second prediction for H4 stated that participants in the EV instructional condition would report lower values for mental workload and CLQ scores than all other instructional conditions. See Table 12 for means and SDs for this analysis.

Table 12

Individual Group Means and Deviations for the NASA-TLX and CLQ

Condition	CLQ		NASA-TLX	
EV	$M = 5.71$	$SD = 1.77$	$M = 39.31$	$SE = 3.24$
ET	$M = 6.32$	$SD = 1.47$	$M = 49.93$	$SE = 3.40$
UV	$M = 6.21$	$SD = 1.60$	$M = 49.59$	$SE = 3.51$
UT	$M = 6.84$	$SD = 1.42$	$M = 54.86$	$SE = 3.35$

First, a one-way ANOVA test was used to analyze CLQ scores for the training session, with instructional condition as the IV. There was a significant effect for instructional condition over the training session on CLQ ratings ($F(3,122) = 2.913$, $p = .037$, $\eta_p^2 = .067$). Planned comparisons revealed a significant difference between the EV ($M = 5.71$, $SD = 1.77$) and UT ($M = 6.84$, $SD = 1.42$) groups, indicating that EV instruction resulted in lower cognitive load than UT instruction, supporting the prediction $F(1,63) = 8.265$, $p = .005$). However, no other comparisons reached significance. Overall results only partially support the prediction.

Next, a one-way ANCOVA was conducted with VGE as the CV to determine the outcome of this prediction. VGE was a significant CV related to the ratings of mental workload ($F(3, 121) = 23.91$, $p < .001$, $\eta_p^2 = 0.17$, $r = -.40$), indicating that higher reported VGE was associated with lower mental workload. There was a significant effect of instructional condition

after controlling for the effects of VGE, $F(3, 121) = 3.964$, $p = .010$, $\eta_p^2 = 0.089$. Planned

contrasts revealed that receiving training in the EV condition did indeed lead to lower levels of

reported mental workload than all other instructional conditions. The EV condition ($M = 39.33$,

$SE = 3.25$) rated workload much lower than all other conditions combined ($M = 51.25$, $SE =$

2.00; $F(1,121 = 9.784$, $p = .002$, $\eta_p^2 = .075$), supporting the prediction. Although significant

differences existed between the EV group and all other individual groups, after controlling for

multiple comparisons using Holm's sequential Bonferroni adjustments, comparisons again

revealed that the EV group was significantly lower than the UT group (Table 13). Overall, H4

prediction 2 was partially supported.

Table 13

Planned Comparisons Between Instructional Conditions on Ratings of Mental Workload During the Training Sessions

		Mean Differences (Effect Size)			
Condition	*M*	1.	2.	3.	4.
1. EV	39.31	--			
2. ET	49.93	-10.63[+]	--		
3. UV	49.59	-10.28[+]	.343	--	
4. UT	54.86	-15.55* (.16)	-4.92	-5.26	--

Note. $* p < .001$. Sig. values adjusted using Holm's sequential bonferroni adjustment for six tests. Effect sizes are reported in η_p^2. [+] Indicates significance at $p < .05$ before Holm's adjustment.

CHAPTER FIVE: DISCUSSION

There is already widespread use of video games for training purposes. This trend is likely to continue as games become both more powerful and more readily accessible. Unfortunately, two major issues have arisen from the rapid rise in GBT technology and application. First, many organizations looking to integrate some form of GBT into their training programs tend to push the newest technology or games simply because they are new and interesting. This means that little or no research is done to determine if the technology leads to effective training and learning. Second, the reported research on GBT is very widespread, covering many different approaches to training but lacking a clear foundation on which to build a model for designing training in games. This shortcoming in the literature has led to numerous research studies reporting mixed findings. A likely cause of these inconsistencies may be from the fact that a lot of research on GBT is focused solely on the results or practicality of the training system or technology designs without fully considering how people learn from these types of game-based interactions.

One of the major benefits of GBT is that it is easily distributed, meaning that individuals are able to train or learn on their own no matter where they are located. This also means that a human facilitator is absent from individual training sessions. Considering the best learning occurs when the learning process is guided, the current effort sought to determine a viable method of developing effective training when game-based environments are used for training and a human facilitator is absent.

The present research sought to provide an empirical approach for applying principles of learning from CTML to GBT instructional design. While many classifications of games exist,

utilizing CTML research for instructional design in GBT was thought to provide the learner-centered focus needed for foundational level support of learning from interactive video games. These types of games are feature-rich, interactive, multimedia presentations, and CTML provides principles for designing and presenting learning material through such presentations. A summary of the results and implications of the findings are presented below.

Summary and Explanation of Results

GBT Retention and CTML

A generally consistent finding for research on CTML is a modality effect supporting voice, rather than text-based, instructional presentations on retention performance (Moreno & Mayer, 1999; Mayer, 2009). That effect was absent in this experiment despite the large effect sizes often observed in research on the modality effect. CTML research also consistently reports a temporal contiguity effect for simultaneous (i.e., embedded) over successive (i.e., upfront) instruction (Mayer, 2001). However, results for this experiment indicated the opposite effect. Even though these results did not support experimental or theoretical predictions, there are a number of possible explanations for why they were observed. First, scores between all conditions were reasonably higher than pre-test scores, indicating an overall increase in learning across the board and potential mutual benefits from receiving any type of instructional presentation. The absence of a modality effect may be due to the sheer amount of information that was presented in the training. Research shows that as the amount of required information increases, the likelihood of remembering that information decreases depending on the individual (e.g., information overload; Chen, Pedersen, & Murphy, 2012). Findings may be a result of an observed ceiling

effect for the benefits of modality based on the amount of information presented. Alternatively, all instructional conditions received both the training information and an opportunity to practice what they learned within the gaming environment. This practice session may have reinforced the information from the training session in the upfront conditions, acting as a type of rehearsal or aiding in recognition of the information, improving the opportunities for learning (Saimpont et al., 2013). Practice led to increased opportunities to form meaningful connections between pieces of information from the instructional presentations and might explain the absence of a modality effect.

Even though CTML sometimes reports mixed results for temporal contiguity and retention, finding the inverse of the expected effect is revealing of some of the possible effects associated with embedding instructional information into a highly interactive gaming environment. The temporal contiguity principle was adapted slightly to account for the inclusion of a game-play practice session. The adjustment was supported by results from previous research on the temporal contiguity principle stating strong support for simultaneous presentation over successive presentation. The adjustment meant that people in the upfront condition still received a multimedia-styled presentation, then subsequently had the opportunity to practice or observe what they learned in the gaming environment prior to learning assessments (i.e., information and practice were separated by time). This may have actually been beneficial for retention of declarative information over the embedded training groups because the potential distractions associated with simultaneous game-play were not present. Upfront learners were better able to focus their attention on the informational presentation of facts and concepts completely and were not required to navigate and interact with the virtual world during instructional delivery. This is

similar to what Mayer reported on mixed results for the temporal contiguity manipulation on retention (Mayer, 2001). Conversely, having to play the game while learning may have acted as a distractor to effective learning of specific declarative knowledge information in the embedded groups. Embedded instruction required constant awareness of the gaming environment, controlling avatar movements, and listening or reading instructional material. The factors not associated with the instruction represent potential sources of extraneous processing required of an already limited working memory and would have inhibited generative processing of the information, leading to lower performance on retention measures.

GBT Transfer and CTML

Modality effects were observed in transfer test results while temporal contiguity effects were not present. Transfer measures a deeper conceptual understanding from the outcomes of training or learning (Mayer, 2009). Learners acquire deeper knowledge through effective training design that takes advantage of the limitations of working memory. In this instance, it was more effective to learn the CLS task through voice instruction, partially supporting experimental predictions and confirming research on modality for transfer performance. This supports the expansion of the modality principle in GBT. Voice-based instruction lowers the extraneous processing requirements of learning material. This may be indicative of the benefits voice-instruction has on learning when considering how WM processes information (Kühl, Scheiter, Gerjets, & Edelmann, 2011). The modality effect is present and is beneficial in GBT on written transfer performance.

The results for this analysis also revealed no benefit of the real-time practice afforded by embedded training. Recall that the upfront conditions still received instructional presentations in

line with a traditional CTML approach (i.e., words and pictures). The major differences between the embedded and upfront condition was the ability of the embedded condition to practice the procedures and apply the knowledge in real-time, taking a guided walkthrough approach. This had no apparent overall effect on transfer performance. The only individual group performance differences existed between the EV and UT instructional groups. At first glance, it would appear that embedded training was also better than upfront training. However, without additional significant findings between groups, it is impossible to determine if these effects are due anything more than the modality effect.

The absence of a temporal contiguity effect on transfer could be because the upfront conditions still received a traditional multimedia presentation (i.e., words and pictures presented together). The differences lied on the instruction-practice timing, rather than the simultaneous-successive one that is typically observed in CTML research. Altering the temporal contiguity principle that incorporated gameplay as the simultaneous-successive factor may have decreased any effects that would have been observed otherwise. On the other hand, it may also be indicative of the idea that, while the temporal contiguity principle does not expand directly into practice-based GBT the same way it applies to traditional CTML, embedding instructional presentations within the game may be just as effective at promoting transfer. Mayer (2014) has noted that the level of immersion within a game does not appear to have beneficial effects on learning outcomes (i.e., 3D versus 2D virtual environments), which may help explain why the use of the temporal contiguity principle herein resulted in no differences between groups. More research is needed to determine the extent of these effects.

Task Performance in GBT and CTML

Of the two in-game application tests administered, only the complex test revealed any benefits due to the instructional delivery method. Failure to find differences on the SAT may be indicative of some of the mixed results in the literature. The SAT was designed as a simple procedural knowledge test, without common environmental stressors typically associated with combat (i.e., where the CLS will more than likely need to use the knowledge and skills learned during training). Using a non-realistic test to measure procedural proficiency may not reveal true aptitude for the task.

The observed effects on the CAT lied between modality on the embedded instruction condition only, with no effects of either individual manipulation observed. The complex test was designed to mimic realistic battlefield conditions in which learners had to demonstrate their knowledge and skills, similar to a procedural transfer task. Modality had no effect within the upfront group, but revealed a large effect within the embedded group with voice instruction leading to much better performance. The voice delivery and inclusion of real-time practice of procedures aligns with expectations from a multimedia learning perspective. The results indicated that CTML partially explains performance of a complex and interactive task learned, and then executed, within a GBT environment, but only on levels of modality when instruction is embedded within the game. This may be because embedded training affords learners the opportunity to process and connect important information to the corresponding procedures more efficiently than text-based embedded instruction that essentially broke the flow of training. The necessity of reading the text instructions on the screen served as a huge source of extraneous processing and severely limited the ability of WM to organize and integrate the procedures (i.e.,

83

gameplay) with the relevant information (i.e., presentation), leading to poor performance. This is an example of the benefits that real-time practice has on learning of complex and involved tasks in GBT environments. The EV condition takes advantage of both the dual-channel assumption and the addition of practice that may act as rehearsal of learned material, which in this context lead to deeper learning.

CAT performance scores between other conditions were not statistically different from one another. Although scoring higher on the test, the EV group performed statistically similarly to both of the upfront groups, and the upfront groups performed similarly to the ET group. The lower scores in the ET group may also be indicative of instructional methods that are too taxing on working memory to link information contextually and procedurally. Text presentation embedded into a gaming environment requires the learner to shift their attention from the relevant procedural pictures (gaming environment) in order to read the training information, resulting in increased extraneous processing (Mayer, 2005; Moreno & Mayer, 1999) and poor performance. Still, the lack of clear main effects makes it difficult to determine the benefits of one method over another outside of embedded instruction.

Mental Workload and Cognitive Load in GBT

Typically, higher levels of cognitive load are associated with lower performance on measures of learning (Paas & Ayres, 2014). While voice instruction led to lower ratings on cognitive load, presentation timing had no effect. Deeper learning requires generative processing to occur in working memory. Generative processing only occurs when there are enough cognitive resources available to effectively process the information and integrate with previous knowledge (Mayer, 2005). Lower ratings in the voice modality condition may be responsible for

observed effects of modality on transfer performance. Since transfer is a measure of deeper conceptual learning of the material, this result provides evidence that voice-based instruction is also beneficial whether embedded in GBT or not. This both supports traditional research on the modality principle and expands its application into GBT. However, the CLQ (Paas, 1992) only contains one item. The mean difference between the modality groups was relatively small (0.65) for a 9-point scale. Even though a significant difference existed between the groups, small difference between ratings make it difficult to accurately interpret meaning from the questionnaire results.

The NASA-TLX is much more sensitive to changes in perceived workload than the CLQ may be for cognitive load. Both voice and embedded instruction (main effects) alleviated mental workload greater than any other condition during the training session. The EV group reported the lowest workload scores, which was consistent with expectations the modality and temporal contiguity principles. Providing voice instruction with actual game-play practice (i.e., embedded) accounts for and supplements CTML's explanation of information processing by considerably lowering the amount of extraneous processing required of the learner. The EV method takes advantage of the dual-channel assumption, the limited capacity assumption, and includes an opportunity to link presented concepts with their corresponding procedural execution in real-time. While EV instruction may not have led to the best performance on all learning measures, the lower mental workload ratings for the EV group reinforces the notion that applying the principles of CTML to GBT sessions may benefit working memory.

Theoretical Implications

Information processing is a central focus in CTML. Research on the theory's numerous principles largely supports the way it explains information processing from multimedia presentations in working memory (Mayer, 2005; Clark & Mayer, 2008; Mayer, 2008). CTML research typically reports these findings in terms of written retention and transfer testing performance. While the findings of traditional CTML research support voice and simultaneous (i.e., embedded) training, the results of this study both support and refute direct application of the modality and temporal contiguity principles to GBT. This is evident in the learning performance differences found between instructional conditions.

The heavily supported findings for voice and simultaneous presentation styles are very different when incorporating a game into the equation. Typically, both retention and transfer are much better when learning from a narrated presentation (Mayer, 2001). The addition of gameplay into the model adjusted these results, leading to different-than-expected effects for temporal contiguity on retention, while modality had no effect. Additionally, no effect for temporal contiguity was found for transfer but the modality effect was quite strong. The application tests did not reveal any effects for either the modality or temporal contiguity principles but did support the use of embedded training (i.e., simultaneous) with voice instruction.

The additional practice of learned knowledge and skills may be enough to negate the effects of modality on retention from instructional presentations in games. Games have a large number of sounds and images that may not be associated with learning. They also require direct interaction from the learner that may not be related to learning and can be visually immersive,

86

which is also hurtful to the learning process depending on prior gaming experience (Wright, Blakely, & Boot, 2012). Each of these factors produces more information to process, which potentially overloads both channels of working memory, despite using both words and pictures, and contributes to extraneous processing, leaving few resources for effective processing of the learning material.

In this sense, the game inhibits the retention of information presented during training by unnecessarily increasing the cognitive requirements to process all incoming information and actions, regardless of delivery modality. This means that the modality principle is not able to predict retention performance in interactive GBT. On the other hand, the temporal contiguity principle successfully extends into GBT but with the opposite effects. Still, this means that at least part of the theory can support predictions when GBT environments are used in addition to training. In these instances, the gameplay itself may act as a form of rehearsal or practice from what was reviewed in the original instructional presentation by providing an opportunity to practice what was learned immediately after learning occurs (Sun, Slusarz, & Terry, 2005).

Transfer effects were only present for the modality principle. Specifically, voice training successfully predicted transfer performance. This finding contributes to the idea that the modality principle of CTML still applies after considering the addition of gameplay with training. This is odd considering modality had no effect on retention. Again, gameplay may have contributed to this outcome. Whether upfront or embedded, receiving information in the auditory channel still frees up valuable resources for deeper processing of information to occur (Mayer, 2008). This means that generative processing was able to occur during instructional presentations

87

regardless of when it was presented. In this instance, the modality effect successfully predicts outcomes in GBT and begins to expand CTML into GBT in general.

The application tests measured application of procedural knowledge. Although not directly referred to as procedural knowledge in much CTML research, some studies examining CTML consider procedural knowledge a type of transfer (van Genuchten, Scheiter, & Schüler, 2012; van Genuchten, van Hooijdonk, Schüler, & Scheiter, 2014). This experiment introduced training for the task within an interactive video game environment, but it was assumed that the principles would still predict performance accurately. The only differences between groups existed on the complex application test between the embedded training groups. This makes sense considering how the theory explains the modality and temporal contiguity principles. Receiving voice-based instruction while practicing the procedures in the game increased the efficiency of WM to organize and integrate these processes, resulting in better learning of the procedure. In contrast, text-based information embedded in GBT requires much more extraneous processing due to the high level of interaction with the game combined with the necessity to read the information on the screen. This further confirms the idea that the modality principle supports deeper knowledge generation in highly interactive GBT.

In summary, the findings of this research begin to explain the effects that an interactive game has on learning in depending on what type of learning is taking place (See Table 14). This alone is an interesting fact to consider. Retention, transfer, and procedural knowledge are fundamentally different types of knowledge (Mayer, 2005; Schneider, Rittle-Johnson, Star, 2011). While consistent results between these types of knowledge appear when the learner takes on a much more passive role in training, much of the previous research only observed highly

simplified information and tasking. When expanding the training to a more realistic domain

consisting of interactive GBT for complex real-life tasks (e.g., the combat medic/lifesaver), these

results may differ. While more research is needed to further confirm findings, results herein

begin to outline a newer model of how information is processed that accounts for game-based

interactions.

Table 14

Taxonomy of Instructional Design Effectiveness on Type of Knowledge in GBT

Type of Knowledge	Modality		Temporal Contiguity	
	Voice	Text	Upfront	Embedded
Declarative (Retention)	--	--	✓	✗
Conceptual (Transfer)	✓	✗	--	--
Procedural (Skill Execution; Simple)	--	--	--	--
Procedural (Skill Execution; Complex/Realistic)	✓	✗	--	✓

Note. "--" Indicates no sig. differences in results; results for retention showed equal levels of improvement for the modality manipulation. Other non-significant findings need further research.

Still, results provide insight for successfully adapting and applying the modality and

temporal contiguity principles to GBT. Although the results were not entirely consistent with

what CTML's model predicts, they were not surprising. Research examining how game-based

interactions affect learning from a GBT system is largely lacking. This effort sought to begin to

bridge the gap between principles of learning and GBT. While findings are mixed in the

traditional CTML sense, they provide the beginnings of possible adaptations to the theory that consider the effects of highly immersive and interactive games used to training.

Practical Implications

Results of this study provide some initial insight into how to develop the most effective training within a GBT environment. Games are entering the educational and training domains at an incredible rate. Unfortunately, the standard practice has become to rush the newest technologies into action before they have been thoroughly tested on their ability to actually lead to effective learning outcomes. While more research is needed, the results presented herein provide a number of practically important applications.

Based on the findings of the current study, instructional guidance in GBT should be developed in tandem with the ability to practice or experience what is being reviewed in real-time. This is particularly important in areas where a conceptual-procedural level of knowledge interconnectivity is required, such as within the medical and military domains. For example, the combat lifesaver task used in this experiment is derived from actual training that the U.S. Army conducts with specialized personnel (Combat Lifesaver Course, 2014). The training involves acquiring an intermediate level of knowledge regarding common combat injuries and the specific skills required to address these issues on the battlefield. Specific games and virtual environments are being developed to aid in the training of these individuals. The results here provide initial guidance for developing instructional material that not only promotes the best approach to deeper learning of the material, but providing training in a way modeled after the EV approach may also help to decrease the time it takes for trainees to reach proficiency. When considering that the

combat lifesaver is responsible for saving lives, the value of fast and efficient training increases dramatically.

In addition, many instances of GBT are used to help bring individuals up to a proficient level before being deployed (i.e., military; Chatham, 2011), beginning a new job (Korteling, Helsdingen, & Theunissen, 2013), or as a means to supplement instruction at home (i.e., education; Jackson & McNamara, (2013). In all of these instances, effective training helps bring individuals to proficiency at a faster rate. This means that findings in this research could lead to better training development in games and better overall learning from individuals. The results of this are more soldiers ready for deployment, more employees capable of performing their jobs, and more students catching up faster and more effectively. In many areas, effective training can lower overall costs associated with training. This means that better training also potentially lowers the necessity of re-training, helps prevent accidents or mistakes, and even helps to save lives that would otherwise be lost due to lack of knowledge and decreasing skill that occurs as a result of decay over time (Kluge & Frank, 2014).

Another area booming in computer and game-based training is the educational domain. Again, games are essentially just sophisticated multimedia presentations. There is already a large assortment of games designed for learning on the market today (Chen, 2014; Girard, Ecalle, & Magnan, 2013). Better instructional design in these games means that students not only acquire deeper knowledge of the material, they also retain the knowledge for longer periods of time (Kluge & Frank, 2014). The results of this study help lay the groundwork for improving upon these types of learning games as well.

In summary, there are many applications where findings from this research may help develop better training programs with consistent results. The guided walk-through approach to developing instruction in GBT may be best for instilling deeper knowledge into novice learners. Guiding learners through virtual practice not only exposes them to similar situations and scenarios that they are likely to encounter in real-life, it also allows them to learn and practice in real-time, learn from mistakes that they make, and make adjustments to their performance. All of these factors aid in development of knowledge and skills (de Jong, 2005; Kalyuga, 2007; Leemkuil & Jong, 2011; Moreno, 2009). The guided walk-through approach takes advantage of all of the assumptions of working memory that drive CTML and, since games are multimedia, is potentially applicable in any type of game incorporating a large amount of interactivity from the learner within an immersive virtual environment. Expanding on these results and applying them to GBT helps provide another step towards the successful deployment of stand-alone, self-paced training systems.

Conclusions

The use of games for training will continue to expand into newer areas, especially in the military and educational domains. This study explored the application of the cognitive theory of multimedia learning to a video game designed for training to determine the viability of expanding the theory to include game-based multimedia presentations. While only partial support for predictions existed, the overall findings begin to indicate how learning may occur differently than expected when using games designed for training, as well as how instructional delivery methods may affect the learning outcomes. Incorporating a voice-based instructional delivery embedded within a gaming environment appears to be a valid starting point for future

GBT development that utilizes this type of interactive game for training depending on the goal of the training. Developing this style of instruction both mimics the instructor-student relationship that is often times missing from GBT and provides the best chance for learners to develop a deeper understanding of the material as they review it without an instructor guiding them through the process.

One of the major shortcomings of research on GBT is that it has lacked a consistent learner-game-interaction-based approach to research and development. The findings from this research extend CTML's model of information processing into the scope of GBT and opens the door for systematically evaluating other theoretically driven instructional design elements within game-based environments. While further research is needed, findings begin to expand on the current structure of CTML to include a model for learning from interactive gaming environments. This structure serves as a guideline for future training development and research that may help instructional developers design GBT that is not only effective, but is also based on solid underlying principles of human learning, even if the principles align differently than what is expected from the research.

In summary, CTML provides a foundation for research that examines instructional design within GBT. The results from this effort begin to show where certain principles of CTML apply directly to, act contradictory with, or have no effect in GBT. This research also adds the consideration of interactive practice into the current model of learning from CTML. Combining instruction into video games brings an entirely new piece to that model. The results from this experiment show that interactions with the gaming environment while learning can both agree with and alter some of the expectations for learning outcomes regularly found in CTML

research. While further research is needed that systematically expands and compares the effects of these and other CTML principles may have on GBT, the results here provide an initial step towards explaining how learning processes are altered when people learn from highly interactive, multimedia-driven games designed for training. It also provides a preliminary basis for potentially altering the model of information processing of CTML when considering GBT.

Study Limitations

Although the results from the study address some of the lacking research regarding GBT and instructional design, there were some limitations. First, the training information used to develop the task for this experiment was pulled entirely from published field manuals for the combat lifesaver. The task for the experiment was substantially thinned for logistical reasons; full training of a combat lifesaver to proficiency on all facets of the task requires 40 hours of both classroom and practical training. Therefore, it is unclear whether results for this specific task actually transfer to the full training required for combat lifesavers. Additionally, measures for proficiency on the 1.5-hour experimental task may not have been equivalent to that required of an actual combat lifesaver. However, learning did occur on the subtasks included in the experiment. It is also unclear if such intensive training could be completely replaced with a game-based analogue, minimizing potential direct external validity to the CLS training task.

Second, integration of embedded training was accomplished through a voice file trigger system built into the TC3 gaming environment. This system only played audio files when a participant navigated within a specified radius around a particular trigger point. While every participant who completed the experiment in the EV group received all of the audio instructions, there were some instances where the audio failed to align with the participant's progress in the

game (those participants were excluded from data analysis). Additionally, once an audio file finished playing, participants were unable to replay the file. A truly intelligent tutoring system would ideally present information to the learner that directly corresponds to their progress and identify when the learner needs additional information or guidance. Technological limitations prevented this capability in this experiment.

Future Research

The results of this study present opportunities for future research to further examine how the immediate learning effects observed in the present study can be translated into specific knowledge and skills that are retained over time. Generally, knowledge and skills decay at a rate depending on a number of factors, including the effectiveness of the original training and the availability of refresher interventions (Kulge & Frank, 2014). This experiment focused mainly on immediate learning outcomes, measured directly after the training session. Therefore, it is impossible to determine how well participants retained the knowledge over a period of time and, in turn, how well the instructional design techniques promoted truly deep and long-term knowledge creation beyond the immediately observed effects. Future research needs to examine how well knowledge and skills from such training are retained and executed over time.

There are numerous researchers examining GBT and how to make it more effective (i.e., feedback, fidelity, instruction). Yet very little focus has been devoted to linking the effects a game may have on learning. The current research focused on a theoretically driven approach to developing and incorporating instruction within GBT with the goal of expanding CTML into more highly interactive games for training. CTML defines roughly 12 principles for designing multimedia instruction, some of which may have implications for learning effectiveness in GBT.

95

Future research needs to expand on the findings here, and examine the effects of each of these principles on instruction within a GBT session. For instance, the results of this study found a reversed temporal contiguity effect for retention. The rationale was that the gameplay might have served as a source of extraneous processing. More research might examine the possible moderating effects of the segmenting principle, which states that people learn better from multimedia instruction when it is presented in user-paced segments (Mayer, 2009). Segmenting larger and more complex training into smaller, learner-controlled sections in GBT may lower distractions caused by game interactions not related to training, lowering the likelihood of overloading the cognitive processes involved in learning (Clark & Mayer, 2011). The signaling (i.e., highlighting the organization and important material) and pre-training principles (i.e., receiving training on the key names and/or characteristics prior to training) may also have significant effects on how people learn from game-based environments.

Additionally, there are numerous types of games used for training purposes. However, there is no clear distinction in the research addressing whether training effectiveness using a certain type of game transfers to another type of game. This is one of the major forces behind the mixed findings on instructional delivery for game and simulation-based training. A future research effort needs to examine the cross-validity of instructional delivery between different types of virtual environments to determine if findings from one GBT system are applicable to other areas within the widespread GBT domain. For example, the results in this study draw conclusions that hint at some of the applicability of CTML in GBT. However, the training game used in this study was a first-person shooter/adventure style game within an open virtual environment. Users viewed and controlled their character using a keyboard and mouse and were

free to roam the virtual environment. Other game-types may be linear and restrictive, allowing

for the same types of controls while keeping the user on a pre-determined path. Another type of

game may act as a turn-based strategy developer that inserts instruction when important

decisions are required. Studying whether or not results are the same between game types is

paramount for the future of game-based learning theory and practice.

Mobile gaming has become one of the most popular mediums for games recently thanks

to the advent of the smartphone, tablet, and wireless internet connectivity (Demo, 2013). More

often than not, mobile games require touch interface from the user on an already crowded screen.

Do results from game-based training and learning research extend to mobile gaming platforms

designed for training? The answer is unclear because of the multitude of different factors

between desktop or console-based GBT versus mobile GBT. Does touch interface interfere with

the view of the training information? Does screen size make a difference when navigating a

virtual environment? Do principles of learning behave as expected under these conditions? All of

these questions are important for advancing new and upcoming technology within the scope of

game-based training.

Finally, it would be noteworthy to examine the relationship between the sampling

population and the typical population performing the task being used in the research. For

example, this research would have compared actual U.S. Army soldiers going through the

combat lifesaver training course with a non-domain specific population (i.e., college students).

Soldiers in the U.S. Army and civilians are generally very different in terms of personality and

expectations, and military service tends to attract a particular type of personality in general

(Jackson, Thoemmes, Jonkmann, Ludthke, & Trautwein, 2012). These distinct population

differences may affect the outcomes of this type of training. It is unclear whether the results for the combat lifesaver task training from an undergraduate civilian population would transfer to a military population. Still, much of the principles of learning that were applied in this research are considered widely generalizable. However, very little research has examined the relationship between a military population and multimedia learning.

APPENDIX A: DEMOGRAPHICS QUESTIONNAIRE

Demographics Questionnaire
Please fill out the following information to the best of your ability. When finished, please click "continue" at the bottom of the page.

Age:

Sex:
○ Male
○ Female

With which hand do you write?
○ Right
○ Left

Have you ever (or do you now) served in the military?
○ Yes
○ No

Have you ever worked in a field related to the medical profession (i.e., doctor, nurse, EMT, etc.)?
○ Yes
○ No

How would you rate your knowledge of first aid?
    1   2   3   4   5

Low ○ ○ ○ ○ ○ High
.

How many hours per week do you use a computer?
○ 0-9
○ 10-19
○ 20-29
○ 30-39

100

○ 40+

How would you rate your computer skills?
○ Beginner
○ Intermediate
○ Expert
○ N/A

APPENDIX B: VIDEO GAME EXPERIENCE QUESTIONNAIRE

Video Game Experience Questionnaire

Please answer the following questions to the best of your ability.

How often do you play PC-based video games that require both the mouse and keyboard, joystick, or similar methods of input?

- ○ Never
- ○ Rarely
- ○ Seldom
- ○ Frequently
- ○ Often

How often so you play console-based video game systems (e.g., PlayStation 3, Xbox 360, Nintendo Wii, etc.)?

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Frequently
- ○ Often

How often (approximately) do you currently play video games?

- ○ Daily
- ○ Weekly
- ○ Monthly
- ○ Rarely
- ○ Never

During an average week, how many hours will you spend playing video games?

- ○ <= 5
- ○ 6-10
- ○ 11-15
- ○ 16-20
- ○ 20+

How often do you play first-person perspective/shooter games (i.e., Halo, Half-life, Call of Duty, etc.)?

○ Never

○ Rarely

○ Sometimes

○ Frequently

○ Often

How would you rate your skill level for first-person/shooter video games?

○ None or Very Low Skill

○ Below Average

○ Average

○ Above Average

○ Expert

APPENDIX C: DECLARATIVE KNOWLEDGE PRE AND POST-TESTS

Knowledge Pre-Test

Please read each of the following questions and answer each to the best of your ability. At this time, you may or may not know the correct answers to each of the questions. Simply select which answer you think is the best.

1. What are the three most common medically preventable causes of death on the modern battlefield?

- ⦿ extremity hemorrhage, tension pneumothorax, airway obstruction
- ○ extremity hemorrhage, tension pneumothorax, gunshot wound
- ○ amputation of a limb, tension pneumothorax, gunshot wound
- ○ amputation of limb, infection, airway obstruction

2. Pulse can be used to indicate the extent of blood loss.

- ○ True
- ○ False

3. You are treating a casualty while under fire. Which of the following can you perform before moving the casualty to a safe place?

- ⦿ Perform cardiopulmonary resuscitation (CPR)
- ○ Apply a tourniquet to control severe bleeding on a limb
- ○ Perform needle decompression to relieve tension pneumothorax
- ○ Administer the combat pill pack to control pain and infection
- ○ × None of the above

4. Which of the following is NOT an important reason to move the casualty to safety?

- ⦿ Lowers the risk of sustaining further injury
- ○ Enables greater levels of casualty care
- ○ Provides an opportunity to reassess initial life saving treatment
- ○ Allows for the preparation and communication necessary for casualty evacuation
- ○ To help keep them quieter to avoid enemy detection

106

5. Why must a penetrating chest wound be sealed?

- ○ To keep air from entering through the wound
- ○ To keep air from escaping through the wound
- ○ To control bleeding
- ○ To prevent infection in the chest cavity
- ○ All of the above

6. When necessary, it is ok to placed a tourniquet over a joint or a fracture site.

- ○ True
- ○ False

7. How many combat lifesavers are typically assigned to each squad, unit, or crew?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

8. Which of the following is NOT one of the phases of Tactical Combat Casualty Care?

- ○ Care under fire
- ○ Tactical field resuscitation
- ○ Tactical evacuation care
- ○ Tactical field care
- ○ All are phases of Tactical Combat Casualty Care

9. When is it appropriate to approach a casualty while under enemy fire?

- ○ As soon as you are ordered to approach by your commanding officer

○ Only after dark so the hostile forces can't see you as well

○ After you have scanned the area around the casualty for potential danger

○ As soon as you realize the casualty requires immediate medical attention

○ Only after the casualty has reported that it is safe to approach

10. There are four classifications used for denoted a casualty's level of consciousness. Which one of the following is NOT one of those classifications?

○ A – The casualty is alert (knows who he is, the date, where he is, etc.)

○ V – The casualty is not alert, but does respond to verbal commands

○ P – The casualty responds to pain, but not to verbal commands

○ U – The casualty is unresponsive (unconscious)

○ D – The casualty is deceased

11. Of the deaths that occur during combat, about what percent die before reaching a medical treatment facility?

○ 10%

○ 35%

○ 50%

○ 75%

○ 90%

12. What medical term means bleeding, usually severe?

○ Blood loss

○ Spurting

○ Hemorrhage

○ Necrosis

○ Genophage

13. After applying a tourniquet in response to an amputation of the arm, how should you treat the stump?

○ Dress and bandage the area

○ Leave exposed to facilitate drainage

○ Wrap the arm tight against the casualty's chest

○ Tell the casualty to hold the arm above his/her head

○ None of the above

14. A tourniquet is NOT used on which of the following body structures?

○ Upper Arm

○ Forearm

○ Thigh

○ Lower Leg

○ Abdomen

15. You are going to the aid of an injured soldier while under fire. What should your first action upon reaching the soldier?

○ Check the soldier for responsiveness

○ Check the soldier's pulse

○ Check the soldier for breathing

○ Check the soldier for shock

○ Check the soldier for bleeding

16. You have treated a casualty with a chest wound. The casualty does not want to sit up. How should you position the casualty?

○ On his back

○ On his front

○ On his side, wounded side up

○ On his side, wounded side down

Knowledge Post-Test

Please read each of the following questions and answer each to the best of your ability. If you are unsure of the correct answer, simply answer to the best of your ability.

1. Your unit is under hostile fire. You see a soldier fall as though he has been shot. Your primary duty is to:

2. Why must a penetrating chest wound be sealed?

3. Why should you push away any loose clothing near a casualty's open wound before applying a dressing?

○ To allow the wound to get air
○ To provide a sterile work area
○ To see the extent of the wound
○ To apply ointment to the wound

4. The combat lifesaver is:

○ A medical soldier whose first duty is to provide medical care to casualties in the battlefield
○ A non-medical soldier who excels in the ability to safely extract casualties from the battlefield
○ A medical soldier trained to emergency medical technician (EMT) level knowledge who provides high-level trauma care to casualties
○ A non-medical soldier who provides lifesaving measures when his combat duties allow him the opportunity
○ None of the above

5. Which one of the following statements gives a proper rule for tightening a tourniquet?

○ A tourniquet should be loose enough so that you can slip two fingers under the tourniquet band
○ A tourniquet should be loose enough so that you can slip the tip of one finger under the tourniquet band
○ A tourniquet is to be tightened until the bright red bleeding has stopped and the distal pulse is gone; darker blood oozing from the wound can be ignored
○ A tourniquet is to be tightened until both the bright red bleeding and the darker venous bleeding have stopped completely and the distal pulse is gone

6. List the types of medication contained in the combat pill pack, carried by every soldier:

7. The casualty has severe bleeding from a wound on his abdomen. Should you apply a tourniquet to control the bleeding?

○ Yes
○ No

8. You are crossing a battlefield after the fighting has stopped and the enemy has retreated. A soldier steps on a land mine and it explodes, giving the soldier a severe wound in his thigh. What phase of care will you be in while rendering care to the soldier?

```



```

9. You see a soldier sitting on the ground. You approach the soldier and ask, "Are you okay?" The soldier responds, "Yeah, but I twisted my ankle when I stepped in a hole." How would you classify this soldier's level of consciousness?

○ A (alert)
○ V (verbal)
○ P (pain)
○ U (unresponsive)
○ D (deceased)

10. Which of the following is NOT considered one of the three most common medically preventable causes of death on the modern battlefield?

○ Penetrating head wounds
○ Bleeding from wounds on the extremities
○ Tension pneumothorax

11. To best control severe arterial bleeding and potentially save a casualty's life, you should most likely:

○ Apply a tourniquet above the bleeding
○ Apply a tourniquet below the bleeding
○ Apply a pressure dressing directly to the source of blood loss
○ Move the casualty to the nearest safe location and prep him/her for MEDEVAC
○ Apply a pressure dressing above the wound and maintain constant, firm pressure

12. Functioning as a combat lifesaver during combat is a soldier's:

○ Overall secondary mission or duty
○ Overall primary mission or duty
○ Primary mission when a casualty is present
○ Priority only when in non-combat situations
○ Priority from the onset of deployment

13. A tourniquet is used to stop blood flow:

○ From the extremity, back towards to heart
○ From the heart, out towards the brain
○ Distal to the tourniquet band
○ Proximal to the tourniquet band
○ From a neck or head area gunshot wound

14. The combat lifesaver's skills can help reduce battlefield deaths by _____. (list the percentage)

15. What is the leading cause of preventable death on the battlefield?

16. Which of the following should you treat first if you and the casualty are in a protected area?

○ Severe arterial bleeding from a limb
○ Breathing difficulties with a penetrating chest wound
○ Severely burned areas on the casualty's body
○ Pain caused by shrapnel within the casualty's abdomen

APPENDIX D: PROBLEM-SOLVING TRANSFER TEST

Knowledge Test 2

Over the next few pages, you will be presented with brief, hypothetical scenarios or situations related to the combat lifesaver. Please read each scenario and provide an answer to the question that follows. Use the knowledge you just obtained to provide what you think is the most appropriate response to the situation.

Please inform the experimenter that you are ready to start. *Please wait for the experiment to tell you when to begin.*

1. You and a fellow soldier are off-duty and relaxing when a shell explosion occurs nearby. You are uninjured in the blast, but the other soldier is now unconscious and is bleeding severely from just above his left knee. You also hear gunshots emanating from just outside your base.

From the combat lifesaver's perspective, what course of action should you follow in order to best address the situation?

2. You are responding to a series of combat injuries when you find a non-responsive casualty lying face-down. The casualty does not appear to be breathing. You hear other casualty's calling for help, but no gunfire is present.

As the combat lifesaver, how should you address the situation?

3. What are the differences between the Care Under Fire and Tactical Field Care phases of care? What are the proper actions for a situation that requires Care Under Fire? Why is it important to follow the correct procedures while attempting to provide Care Under Fire?

APPENDIX E: IRB APPROVAL LETTERS

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Stephen R. Serge** and Co-PIs: **Glenn A. Martin, Heather A. Priest, Mustapha Mouloua**

Date: **February 18, 2014**

Dear Researcher:

On 2/18/2014, the IRB approved the following human participant research until 2/17/2015 inclusive:

Type of Review:	UCF Initial Review Submission Form
Project Title:	A Multimedia Approach to Game-Based Training: Expanding the Effects of Modality and Temporal Contiguity on Learning of a Complex Task
Investigator:	Stephen R Serge
IRB Number:	SBE-14-10037
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 2/17/2015, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 02/18/2014 03:50:16 PM EST

IRB Coordinator

Page 1 of 1

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Stephen R. Serge** and Co-PI: **Glenn A. Martin, Heather A. Priest, Mustapha Mouloua**

Date: **April 28, 2014**

Dear Researcher:

On 4/28/2014, the IRB approved the following minor modification to human participant research until 02/17/2015 inclusive:

Type of Review:	IRB Addendum and Modification Request Form Expedited Review Category #7
Modification Type:	The total number of study participants has been increased from 168 to 250 individuals. A revised Informed Consent document has been approved for use.
Project Title:	A Multimedia Approach to Game-Based Training: Expanding the Effects of Modality and Temporal Contiguity on Learning of a Complex Task
Investigator:	Stephen R Serge
IRB Number:	SBE-14-10037
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 02/17/2015, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a signed and dated copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Page 1 of 2

Joanne Muratori

IRB Coordinator

118

REFERENCES

Atkinson, R. K., & Renkl, A. (2007). Interactive example-based learning environments: Using interactive elements to encourage effective processing of worked examples. *Educational Psychology Review*, *19*(3), 375-386. doi:10.1007/s10648-007-9055-2

Baddeley, A. (1992). Working memory. *Science*, *255*(5044), 556-559. doi:10.1126/science.1736359

Baniqued, P. L., Lee, H., Voss, M. W., Basak, C., Cosman, J. D., DeSouza, S., & Kramer, A. F. (2013). Selling points: What cognitive abilities are tapped by casual video games?. *Acta Psychologica*, *142*(1), 74-86. doi:10.1016/j.actpsy.2012.11.009

Billings, D. R. (2012). Efficacy of adaptive feedback strategies in simulation-based training. *Military Psychology*, *24*(2), 114-133. doi:10.1080/08995605.2012.672905

Bohemian Interactive (2013). VBS2. http://products.bisimulations.com/products/vbs2/overview

Breakaway Ltd. (2012). Serious Games. *Pulse!!*. http://www.breakawayltd.com/serious-games/solutions/healthcare/

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review*, *31*21-32.

Cameron, B., & Dwyer, F. (2005). The Effect of Online Gaming, Cognition and Feedback Type in Facilitating Delayed Achievement of Different Learning Objectives. *Journal Of Interactive Learning Research*, *16*(3), 243-258.

Cantor, N. (1946). The Function of the Instructor and the Responsibility of the Student. In , *Dynamics of learning* (pp. 77-94). Buffalo, NY US: Foster & Stewart. doi:10.1037/11472-005

Center for Army Lessons Learned. (2010). *Handbook: Tactical Combat Casualty Care*, No. 10-44.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition And Instruction*, *8*(4), 293-332. doi:10.1207/s1532690xci0804_2

Chatham, R. (2011). After the revolution: Game-informed training in the U.S. Military. In S. Tobias, J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 73-99). Charlotte, NC, US: IAP Information Age Publishing.

Chen, C., Pedersen, S., & Murphy, K. L. (2012). The influence of perceived information overload on student participation and knowledge construction in computer-mediated communication. *Instructional Science, 40*(2), 325-349. doi:10.1007/s11251-011-9179-0E

Chen, J. C., & Joyner, C. T. (2009). Concurrent performance of gunner's and robotics operator's tasks in a multitasking environment. *Military Psychology*, *21*(1), 98-113. doi:10.1080/08995600802565785

Chen, Z. (2014). Exploring students' behaviors in a competition-driven educational game. *Computers in Human Behavior, 35,*68-74. doi:10.1016/j.chb.2014.02.021

Cheng, M. & Annetta, L. (2012). Students' learning outcomes and learning experience through playing a Serious Educational Game. *Journal of Biological Education,46*(4), 203-213.

Clark, R., & Mayer, R. E. (2008). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning (2nd ed.)*. San Francisco, CA US: Pfeiffer/John Wiley & Sons.

Clark, R. C., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*. San Francisco, CA: Pfieffer, A Wiley Imprint.

Combat Lifesaver Course (February, 2014). Retrieved from http://www.carson.army.mil/mstc/cls.html

Dalgarno, B., & Lee, M. W. (2010). What are the learning affordances of 3-D virtual environments?. *British Journal Of Educational Technology*, *41*(1), 10-32. doi:10.1111/j.1467-8535.2009.01038.x

de Jong, T. (2005). The Guided Discovery Principle in Multimedia Learning. In R. E. Mayer (Ed.) , *The Cambridge handbook of multimedia learning* (pp. 215-228). New York, NY US: Cambridge University Press.

Demo, J. (November, 2013). *The Rise and Rise of Mobile Gaming.* Retrieved from http://gamingbolt.com/the-rise-and-rise-of-mobile-gaming

Deal, K. H., Bennett, S., Mohr, J., & Hwang, J. (2011). Effects of field instructor training on student competencies and the supervisory alliance. Research on Social Work Practice, 21(6) 712-726

Delahaij, R., van Dam, K., Gaillard, A.W.K., & Soeters, J. (2011). Predicting Performance Under Acute Stress: The Role of Individual Characteristics. *International Journal of Stress Management, 18*(1), 49-66. doi: 10.1037/a0020891

DeRouin-Jessen, R. E. (2010). Game on: The impact of game features in computer-based training. *Dissertation Abstracts International*, *71*(6-B), 3974.

Diaz, D. D. & Sims, V.K. (2003). Augmenting virtual environments: the influence of spatial ability on learning from integrated displays. *High Ability Studies, 14*(2), 191-212.

Dickey, M. D. (2006). Game Design Narrative for Learning: Appropriating Adventure Game Design Narrative Devices and Techniques for the Design of Interactive Learning Environments. *Educational Technology Research And Development*, *54*(3), 245-263. doi:10.1007/s11423-006-8806-y

Dickey, M. D. (2011). Murder on Grimm Isle: The impact of game narrative design in an educational game-   based learning environment. *British Journal Of Educational Technology*, *42*(3), 456-469. doi:10.1111/j.1467-8535.2009.01032.x

Driskell, J. E., & Johnston, J. H. (1998). Stress exposure training. In J. A. Cannon-Bowers, E. Salas (Eds.) , *Making decisions under stress: Implications for individual and team training* (pp. 191-217). American Psychological Association. doi:10.1037/10278-007

Driskell, J.E., Salas, E., Johnston, J.H., & Wollert, T.N. (2008). Stress Exposure Training: An Event-Based Approach. In P.A. Hancock & J.L. Szalma (Eds.), *Performance Under Stress* (101-114). Burlington, VT: Ashgate Publishing Company.

Duffy, V. G., Ng, P. W., & Ramakrishnan, A. (2004). Impact of a simulated accident in virtual training on decision-making performance. *International Journal Of Industrial Ergonomics*, *34*(4), 335-348. doi:10.1016/j.ergon.2004.04.012

ECS. (2007). *ECS Tactical Combat Casualty Care (TC3) Chosen as I/ITSEC 2007 Serious Games Finalist.* Retrieved from http://www.ecsorl.com/ecs-tactical-combat-casualty-care-tc3-chosen-as-iitsec-2007-serious-games-finalist/

Elliott, J. C., & Giesbrecht, B. (2010). Perceptual load modulates the processing of distractors presented at task-irrelevant locations during the attentional blink. *Attention, Perception, & Psychophysics*, *72*(8), 2106-2114. doi:10.3758/APP.72.8.2106

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160.

Field, A. P. (2005). *Discovering statistics using SPSS: and sex and drugs and rock 'n' roll* (2nd edition). London: Sage publications.

Field, A. P., & Hole, G. J. (2003). *How to design and report experiments*. London: Sage publications.

Fiorella, L., Vogel-Walcutt, J. J., & Schatz, S. (2012). Applying the modality principle to real-time feedback and the acquisition of higher-order cognitive skills. *Educational Technology Research And Development*, *60*(2), 223-238. doi:10.1007/s11423-011-9218-1

Fischer, P., Kubitzki, J., Guter, S., & Frey, D. (2007). Virtual driving and risk taking: Do racing games increase risk-taking cognitions, affect, and behaviors?. *Journal Of Experimental Psychology: Applied*, *13*(1), 22-31. doi:10.1037/1076-898X.13.1.22

Friedland, N. & Keinan, G. (1992). Training effective performance in stressful situations: Three approaches and implications for combat training. *Military Psychology*, 4(3): 157–174.

Gega, L. L., Norman, I. J., & Marks, I. M. (2007). Computer-aided vs. tutor-delivered teaching of exposure therapy for phobia/panic: Randomized controlled trial with pre-registration nursing students. *International Journal of Nursing Studies*, *44*(3), 397-405. doi:10.1016/j.ijnurstu.2006.02.009

Girard, C. C., Ecalle, J. J., & Magnan, A. A. (2013). Serious games as new educational tools: How effective are they? A meta-   analysis of recent studies. *Journal of Computer Assisted Learning, 29*(3), 207-219.

Goldstein, I. L. and Ford, J. K. (2002). Training in Organizations, 4th ed. Belmont, CA: Wadsworth Thompson Learning.

Guillén-Nieto, V., & Aleson-Carbonell, M. (2012). Serious games and learning effectiveness: The case of it's a deal!. *Computers & Education*, *58*(1), 435-448. doi:10.1016/j.compedu.2011.07.015

Hancock, P.A. & Szalma, J.L. (2008). Stress and Performance. In P.A. Hancock & J.L. Szalma (Eds.), *Performance Under Stress* (101-114). Burlington, VT: Ashgate Publishing Company.

Harris, W.C., Ross, K.G., & Hancock, P.A. (2008). Changes in Soldier's Information Processing Capability under Stress. In P.A. Hancock & J.L. Szalma (Eds.), *Performance Under Stress* (101-114). Burlington, VT: Ashgate Publishing Company.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock, N. Meshkati (Eds.) , *Human mental workload* (pp. 139-183). Oxford, England: North-Holland. doi:10.1016/S0166-4115(08)62386-9

Hegarty, M., & Waller, D. (2004). A dissociation between mental rotation and perspective-taking spatial abilities. *Intelligence*, *32*(2), 175-191. doi:10.1016/j.intell.2003.12.001

Harskamp, E. G., Mayer, R. E., & Suhre, C. (2007). Does the modality principle for multimedia learning apply to science classrooms?. *Learning And Instruction*, *17*(5), 465-477. doi:10.1016/j.learninstruc.2007.09.010

Hockey, G. J., Sauer, J., & Wastell, D. G. (2007). Adaptability of Training in Simulated Process Control: Knowledge-Versus Rule-Based Guidance Under Task Changes and Environmental Stress. *Human Factors*, *49*(1), 158-174. doi:10.1518/001872007779598000

Holm, S. 1979. A simple sequential rejective multiple test procedure. *Scandinavian Journal of Statistics 6*, 65-70.

Howard, M. W., & Kahana, M. J. (2002). A distributed representation of temporal context. *Journal Of Mathematical Psychology*, *46*(3), 269-299. doi:10.1006/jmps.2001.1388

Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R.E., & DaRosa, D.A. (2011). Applying multimedia design principles enhances learning in medical education. *Medical Education, 45*, 818-826. doi:10.1111/j.1365-2923.2011.03988.x

Jackson, G., & McNamara, D. S. (2013). Motivation and performance in a game-based intelligent tutoring system. *Journal of Educational Psychology*, 105(4), 1036-1049. doi:10.1037/a0032580

Jackson, J. J., Thoemmes, F., Jonkmann, K., Lüdtke, O., & Trautwein, U. (2012). Military training and personality trait development: Does the military make the man, or does the man make the military?.*Psychological Science*, *23*(3), 270-277. doi:10.1177/0956797611423545

Kahana, M. J., Howard, M. W., & Polyn, S. M. (2008). Associative retrieval processes in episodic memory. In J. Byrne (Series Ed.) & H. L. Roediger III (Vol. Ed.), *Learning and memory: Vol. 2*. *Cognitive psychology of memory* (pp. 467-490). Oxford: Elsevier

Kalyuga, S. (2007). Enhancing instructional efficiency of interactive e-learning environments: A cognitive load perspective. *Educational Psychology Review*, *19*(3), 387-399. doi:10.1007/s10648-007-9051-6

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing Split-attention and Redundancy in Multimedai Instruction. *Applied Cognitive Psychology, 13,* 351-371.

Keinan, G., Friedland, N., & Sarig-Naor, V. (1990). Training for task performance under stress: The effectiveness of phased training methods. *Journal Of Applied Social Psychology*, *20*(18, Pt 2), 1514-1529. doi:10.1111/j.1559-1816.1990.tb01490.x

Kersh, B. Y. (1962). The motivating effect of learning by directed discovery. *Journal Of Educational Psychology*, *53*(2), 65-71. doi:10.1037/h0044269

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist*, *41*(2), 75-86. doi:10.1207/s15326985ep4102_1

Kluge, A., & Burkolter, D. (2013). Enhancing research on training for cognitive readiness: Research issues and experimental designs. *Journal Of Cognitive Engineering And Decision Making*, *7*(1), 96-118. doi:10.1177/1555343412446483

Kluge, A. & Frank, B. (2014). Counteracting skill decay: four refresher interventions and their effect on skill and knowledge retention in a simulated process control task. *Ergonomics, 57*(4), 175-190, doi: 10.1080/00140139.2013.869357

Korteling, H., Helsdingen, A., & Theunissen, N. M. (2013). Serious gaming @ work: Learning job-related competencies using serious gaming. In D. Derks, A. B. Bakker (Eds.), *The psychology of digital media at work* (pp. 123-144). New York, NY, US: Psychology Press.

Kozhevnikov, M., & Hegarty, M. (2001). A dissociation between object manipulation spatial ability and spatial orientation ability. *Memory & Cognition*, *29*(5), 745-756. doi:10.3758/BF03200477

Krahenbuhl, G. (1981). Instructor pilot teaching behavior and student pilot stress in flight training. *Aviation, Space, And Environmental Medicine*, *52*(10), 594-597.

Kühl, T., Scheiter, K., Gerjets, P., & Edelmann, J. (2011). The influence of text modality on learning with static and dynamic visualizations. *Computers in Human Behavior, 27*(1), 29-35. doi:10.1016/j.chb.2010.05.008

Lee, H., Boot, W. R., Basak, C., Voss, M. W., Prakash, R., Neider, M., & ... Kramer, A. F. (2012). Performance gains from directed training do not transfer to untrained tasks. *Acta Psychologica*, *139*(1), 146-158. doi:10.1016/j.actpsy.2011.11.003

Leemkuil, H., & de Jong, T. (2011). Instructional Support in Games. In S. Tobias, J. D. Fletcher (Eds.) , *Computer games and instruction* (pp. 353-369). Charlotte, NC US: IAP Information Age Publishing.

Leung, G. C., Yuce, G., & Duffy, V. G. (2010). The effects of virtual industrial training on mental workload during task performance. *Human Factors And Ergonomics In Manufacturing & Service Industries*, *20*(6), 567-578. doi:10.1002/hfm.20198

Litt, A., Reich, T., Maymin, S., & Shiv, B. (2011). Pressure and perverse flights to familiarity. *Psychological Science*, *22*(4), 523-531. doi:10.1177/0956797611400095

Mané, A. M., Adams, J. A., & Donchin, E. (1989). Adaptive and part-whole training in the acquisition of a complex perceptual-motor skill. *Acta Psychologica*, *71*(1-3), 179-196. doi:10.1016/0001-6918(89)90008-5

Mason, R., & Patterson, E. (2013). War gaming peace operations. *Simulation & Gaming*, *44*(1), 118-133. doi:10.1177/1046878112455490

Masson, M. J., Bub, D. N., & Lalonde, C. E. (2011). Video-game training and naïve reasoning about object motion. *Applied Cognitive Psychology*, *25*(1), 166-173. doi:10.1002/acp.1658

Mayer, R. E. (2001). *Multimedia learning*. New York, NY US: Cambridge University Press.

Mayer, R. E. (2002). Psychology's elusive search for transfer. *Psyc Critiques*, *47*(3), 266-267. doi:10.1037/001115

Mayer, R. E. (2004). Should There Be a Three-Strikes Rule Against Pure Discovery Learning?. *American Psychologist*, *59*(1), 14-19. doi:10.1037/0003-066X.59.1.14

Mayer, R. E. (2005). Introduction to Multimedia Learning. In R. E. Mayer (Ed.) , *The Cambridge handbook of multimedia learning* (pp. 1-16). New York, NY US: Cambridge University Press.

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist*, *63*(8), 760-769. doi:10.1037/0003-066X.63.8.760

Mayer, R. E. (2009). *Multimedia learning (2nd ed.)*. New York, NY US: Cambridge University Press.

Mayer, R.E. (2014). *Computer Games for Learning: An Evidence-Based Approach*. Cambridge, MA US: The MIT Press.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal Of Educational Psychology*, *84*(4), 444-452. doi:10.1037/0022-0663.84.4.444

Mayer, R. E., Bove, W., Bryman, A., Mars, R., & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal Of Educational Psychology*, *88*(1), 64-73. doi:10.1037/0022-0663.88.1.64

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages?. *Journal Of Educational Psychology*, *93*(2), 390-397. doi:10.1037/0022-0663.93.2.390

Mayer, R. E., & DaPra, C. (2012). An embodiment effect in computer-based learning with animated pedagogical agents. *Journal Of Experimental Psychology: Applied*, *18*(3), 239-252. doi:10.1037/a0028616

Mayer, R. E., & Johnson, C. I. (2010). Adding instructional features that promote learning in a game-like environment. *Journal Of Educational Computing Research*, *42*(3), 241-265. doi:10.2190/EC.42.3.a

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal Of Educational Psychology*, *90*(2), 312-320. doi:10.1037/0022-0663.90.2.312

Mayer, R. E., & Moreno, R. (2002). Aids to computer-based multimedia learning. *Learning And Instruction*, *12*(1), 107-119. doi:10.1016/S0959-4752(01)00018-4

Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal Of Educational Psychology*, *91*(4), 638-643. doi:10.1037/0022-0663.91.4.638

Mayers, A. (2013). Introduction to Statistics and SPSS in Psychology. Pearson Education Limited: Upper Saddle River, New Jersey.

Merat, N., Jamson, A., Lai, F. H., & Carsten, O. (2012). Highly automated driving, secondary task performance, and driver state. *Human Factors*, *54*(5), 762-771. doi:10.1177/0018720812442087

Moreno, R. (2006). Does the modality principle hold for different media? A test of the method-affects-learning hypothesis. *Journal Of Computer Assisted Learning*, *22*(3), 149-158. doi:10.1111/j.1365-2729.2006.00170.x

Moreno, R. (2009). Learning from animated classroom exemplars: The case for guiding student teachers' observations with metacognitive prompts. *Educational Research And Evaluation*, *15*(5), 487-501. doi:10.1080/13803610903444592

Moreno, R. & Mayer, R.E. (1999). Cognitive Principles of Multimedia Learning: The Role of Modality and Contiguity. *Journal of Educational Psychology, 91*(2), 358-368. doi:10.1037/0022-0663.91.2.358

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. *Journal of Educational Psychology*, *94*(3), 598-610. doi:10.1037/0022-0663.94.3.598

Neumann, J. L. (2007). Effect of operator control configuration on unmanned aerial system trainability. *Dissertation Abstracts International*, *67*, 6760.

Nicolescu, M., Leigh, R., Olenderski, A., Louis, S., Dascalu, S., Miles, C., & Aleson, R. (2007). A training simulation system with realistic autonomous ship control. *Computational Intelligence*, *23*(4), 497-516. doi:10.1111/j.1467-8640.2007.00318.x

O'Neil H.F., Mayer R.E., Herl H.E., Niemi C., Olin K. & Thurman A. (2000) Instructional strategies for virtual aviation training environments. In H.F. O'Neil & D.H. Andrews (Eds.) *Aircrew Training and Assessment* (pp. 105–130). Erlbaum, Mahwah, NJ.

Orvis, K. A., Horn, D. B., & Belanich, J. (2009). An examination of the role individual differences play in videogame-based training. *Military Psychology*, *21*(4), 461-481. doi:10.1080/08995600903206412

Paas, F.C. (1992). Training strategies for attaining transfer of problem-solving skills in statistics: A cognitive-load approach. *Journal of Educational Psychology*, *84*(4), 429-434.

Paas, F., & Ayres, P. (2014). Cognitive load theory: A broader view on the role of memory in learning and education. *Educational Psychology Review, 26*(2), 191-195. doi:10.1007/s10648-014-9263-5

Paas, F. C., & Van Merriënboer, J. G. (1994). Instructional control of cognitive load in the training of complex cognitive tasks. *Educational Psychology Review*, *6*(4), 351-371. doi:10.1007/BF02213420

Paivio, A. (1971). *Imagery and verbal processes*. Oxford England: Holt, Rinehart & Winston.

Paivio, A. (2007). *Mind and its evolution: A dual coding theoretical approach*. Mahwah, NJ US: Lawrence Erlbaum Associates Publishers.

Pallant, J. (2007). *SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows (3rd edition),* Open University Press.

Przybylski, A. K., Rigby, C., & Ryan, R. M. (2010). A motivational model of video game engagement. *Review of General Psychology*, *14*(2), 154-166. doi:10.1037/a0019440

Renkl, A., Atkinson, R. K., & Groβe, C. S. (2004). How Fading Worked Solution Steps Works - A Cognitive Load Perspective. *Instructional Science*, *32*(1-2), 59-82. doi:10.1023/B:TRUC.0000021815.74806.f6

Rhienmora, P., Haddawy, P., Suebnukarn, S., & Dailey, M. N. (2011). Intelligent dental training simulator with objective skill assessment and feedback. *Artificial Intelligence in Medicine*, *52*(2), 115-121. doi:10.1016/j.artmed.2011.04.003

Richardson, A. E., Powers, M. E., & Bousquet, L. G. (2011). Video game experience predicts virtual, but not real navigation performance. *Computers in Human Behavior*, *27*(1), 552-560. doi:10.1016/j.chb.2010.10.003

Saks, A. M., & Burke, L. A. (2012). An investigation into the relationship between training evaluation and the transfer of training. *International Journal Of Training And Development*,*16*(2), 118-127. doi:10.1111/j.1468-2419.2011.00397.x

Saimpont, A., Lafleur, M. F., Malouin, F., Richards, C. L., Doyon, J., & Jackson, P. L. (2013). The comparison between motor imagery and verbal rehearsal on the learning of sequential movements. *Frontiers in Human Neuroscience*, *7*doi:10.3389/fnhum.2013.00773

Sanchez, E. & Garcia-Rodicio, H. (2008). The use of modality in the design of verbal aids in computer-based learning environments. *Interacting with Computers, 20,* 545-561. doi:10.1016/j.intcom.2008.08.001

Schmider, E., Ziegler, M., Danay, E., Beyer, L., & Bühner, M. (2010). Is it really robust? Reinvestigating the robustness of ANOVA against violations of the normal distribution assumption. *Methodology: European Journal Of Research Methods For The Behavioral And Social Sciences*, *6*(4), 147-151. doi:10.1027/1614-2241/a000016

Schneider, M., Rittle-Johnson, B., & Star, J. R. (2011). Relations among conceptual knowledge, procedural knowledge, and procedural flexibility in two samples differing in prior knowledge. *Developmental Psychology, 47*(6), 1525-1538. doi:10.1037/a0024997

SederBerg, P. B., Miller, J. F., Howard, M. W., & Kahana, M. J. (2010). The temporal contiguity effect predicts episodic memory performance. *Memory & Cognition*, *38*(6), 689-699. doi:10.3758/MC.38.6.689

Serge, S. R., Priest, H. A., Durlach, P. J., & Johnson, C. I. (2013). The effects of static and adaptive performance feedback in game-based training. *Computers in Human Behavior*, *29*(3), 1150-1158. doi:10.1016/j.chb.2012.10.007

Sitzmann, T. (2011). A meta- analytic examination of the instructional effectiveness of computer- based simulation games. *Personnel Psychology*, *64*(2), 489-528. doi:10.1111/j.1744-6570.2011.01190.x

Smeeton, N. J., Williams, A., Hodges, N. J., & Ward, P. (2005). The Relative Effectiveness of Various Instructional Approaches in Developing Anticipation Skill. *Journal Of Experimental Psychology: Applied*, *11*(2), 98-110. doi:10.1037/1076-898X.11.2.98

Smith, R. (2010). The long history of gaming in military training. *Simulation & Gaming*, *41*(1), 6-19. doi:10.1177/1046878109334330

Sotomayor, T. M. (2010). Teaching tactical combat casualty care using the TC3 Sim game-based simulation: A study to measure training effectiveness. *Annual Review of Cybertherapy And Telemedicine*, *8*140-143.

Stetz, M., Wiederhold, B.K., & Wildzunas, R. (2006). Usefulness of virtual reality stress inoculation training for military medical females. *Cyberpsychology and Behavior, 9*, 719–720.

Sun, R., Slusarz, P., & Terry, C. (2005). The Interaction of the Explicit and the Implicit in Skill Learning: A Dual-Process Approach. *Psychological Review, 112*(1), 159-192. doi:10.1037/0033-295X.112.1.159

Sweller, J. (2011). Cognitive load theory. In J. P. Mestre, B. H. Ross (Eds.) , *The psychology of learning and motivation (Vol 55): Cognition in education* (pp. 37-76). San Diego, CA US: Elsevier Academic Press. doi:10.1016/B978-0-12-387691-1.00002-8

Thomas, L. C., & Wickens, C. D. (2006). Effects of battlefield display frames of reference on navigation tasks, spatial judgments, and change detection. *Ergonomics*, *49*(12-13), 1154-1173. doi:10.1080/00140130600612655

Thompson, M. E., Ford, R., & Webster, A. (2011). Effectiveness of interactive, online games in learning neuroscience and students' perception of the games as learning tools. *Journal of Allied Health*, *40*(3), 150-155.

Tichon, J. G., & Wallis, G. M. (2010). Stress training and simulator complexity: Why sometimes more is less. *Behaviour & Information Technology*, *29*(5), 459-466. doi:10.1080/01449290903420184

Trybus, J. (2012). Game-Based Learning: What it is, Why it Works, and Where it's Going [Web log post]. Retrieved from http://www.newmedia.org/game-based-learning--what-it-is-why-it-works-and-where-its-going.html

U.S. Army Medical Department Center and School. (2010). *Combat Lifesaver Course: Student Self-Study,* ISO871.

van Genuchten, E., Scheiter, K., & Schüler, A. (2012). Examining learning from text and pictures for different task types: Does the multimedia effect differ for conceptual, causal, and procedural tasks?. *Computers in Human Behavior, 28*(6), 2209-2218. doi:10.1016/j.chb.2012.06.028

van Genuchten, E., van Hooijdonk, C., Schüler, A., & Scheiter, K. (2014). The role of working memory when 'learning how' with multimedia learning material. *Applied Cognitive Psychology, 28*(3), 327-335. doi:10.1002/acp.2998

van Merriënboer, J. G., & Sweller, J. (2005). Cognitive Load Theory and Complex Learning: Recent Developments and Future Directions. *Educational Psychology Review*, *17*(2), 147-177. doi:10.1007/s10648-005-3951-0

Veltman, J. A., & Gaillard, A. K. (1998). Physiological workload reactions to increasing levels of task difficulty. *Ergonomics*, *41*(5), 656-669. doi:10.1080/001401398186829

Vernadakis, N., Gioftsidou, A., Antoniou, P., Ioannidis, D., & Giannousi, M. (2012). The impact of Nintendo Wii to physical education students' balance compared to the traditional approaches. *Computers & Education*, *59*(2), 196-205. doi:10.1016/j.compedu.2012.01.003

Vogel- Walcutt, J. J., Gebrim, J. B., Bowers, C. C., Carper, T. M., & Nicholson, D. D. (2011). Cognitive load theory vs. Constructivist approaches: Which best leads to efficient, deep learning?. *Journal of Computer Assisted Learning*, *27*(2), 133-145. doi:10.1111/j.1365-2729.2010.00381.x

Waller, D. (2000). Individual differences in spatial learning from computer-simulated environments. *Journal Of Experimental Psychology: Applied*, *6*(4), 307-321. doi:10.1037/1076-898X.6.4.307

Wallet, G., Sauzéon, H., Pala, P., Larrue, F., Zheng, X., & N'Kaoua, B. (2011). Virtual/real transfer of spatial knowledge: Benefit from visual fidelity provided in a virtual environment and impact of active navigation. *Cyberpsychology, Behavior, And Social Networking*, *14*(7-8), 417-423. doi:10.1089/cyber.2009.0187

Webb, N. (1999). Play therapy crisis intervention with children. In N. Webb (Ed.), *Play therapy with children in crisis: Individual, group, and family treatment (2nd ed.)* (pp. 39-46). New York, NY US: Guilford Press.

Weiner, G. M., Menghini, K., Zaichkin, J., Caid, A. E., Jacoby, C. J., & Simon, W. M. (2011). Self-directed versus traditional classroom training for neonatal resuscitation. *Pediatrics*, *127*(4), 713-719. doi:10.1542/peds.2010-2829

Wright, T., Blakely, D. P., & Boot, W. R. (2012). The effects of action video game play on vision and attention. In J. Gackenbach (Ed.), *Video game play and consciousness* (pp. 65-82). Hauppauge, NY, US: Nova Science Publishers.

Wu, W. H., Hsiao, H. C., Wu, P. L., Lin, C. H., & Huang, S. H. (2012). Investigating the learning theory foundations of game based learning: A meta-analysis. *Journal of Computer Assisted Learning*, *28*(3), 265-279.