The Effects of Stereoscopic 3D on an Incidence Response Training Game

by

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Abstract

A critical incident is defined as one of the most serious situations that can occur at any institution. Among these critical incidents are fire hazards, which resulted in 224 civilian deaths, and approximately 1.5$ billion dollars in direct property damage in Canada in 2011 alone. As a result of these costs, much effort is currently being placed in both fire safety prevention and fire safety evacuation. However, many current training techniques come at a high cost, and remain ineffective for real life fire situations, especially those which take place in large institutions. An example of this can be seen in university chemical labs, which hold many hazardous and flammable materials. In this thesis, the development of an incidence response training game for chemical lab fires is described. Serious games leverage the power of computer games to captivate and engage players/learners for a specific purpose such as to develop new knowledge or skills. Not only do serious games allow for higher engagement rates, and easier distribution than current training techniques, but by utilizing stereoscopic 3D (S3D) technologies it is hypothesized by many researchers that even higher engagement rates as well as knowledge retention levels can be reached. However, there is a lack of research examining the effects of S3D within an incidence response serious game. In this thesis, three experiments were conducted to examine potential benefits of employing S3D within a serious game for incidence response: i) engagement effects with S3D, ii) calibration of S3D settings, and iii) knowledge retention levels with S3D.

The results of these experiments revealed that users were neither more engaged, nor did they increase their knowledge retention with the incorporation of S3D, contrary to prior research. Furthermore, allowing a user to define their own S3D settings is critical, and the inability to do so may create visual discomfort or an unnoticeable S3D effect.

Keywords: Serious games, incidence response, training, learning, education, stereoscopic 3D.

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Chapter 1

Introduction

1.1 Motivation

A critical incident is defined as one of the most serious situations that can occur at any institution and can be described as any of the following: bomb threat, armed person,assault, biohazardous spill, animal rights protest or damaging activities of research labs, civil disobedience, electrical outage, fire or explosion, gas leak, winter weather storms (and other natural disasters), terrorist threat, or a suicide or sexual assault [73]. Among these critical incidents is the risk of fire, one of the greatest threats to health and safety, property and the delivery of essential services [82]. Every workplace must have an incidence response plan set out (generally dictated by law), although the employees of most workplaces are not prepared to properly handle a critical incidence should one arise in the workplace.

Canadian fire statistics reveal that hundreds of Canadians lose their lives or suffer injuries, and over a billion dollars in property is lost every year due to fires [111]. In 2011, Canada had a total of 42,753 fires which resulted in 224 civilian deaths, two fire-fighter deaths, and approximately \$1.5 billion dollars in direct property damage [111]. As a result of these costs, much effort is currently being placed in both fire safety prevention and fire safety evacuation. Human Resources and Skills Development Canada (HRSDC) is providing participants with guides to help those who are responsible for the development of an effective, workable Fire Emergency Organization and Fire Safety Plan [82]. These guides are created for the industry sector as opposed to the home sector which have very different issues altogether. The guides entail details on how to deal with both evacuation scenarios (immediate or two-stage) as well as detailed instructions for specific cases such as; forming a fire emergency organization, evacuating mobility impaired persons, and many other guides to be used by private organizations [82]. With proper education and training, lives can be saved, and both time and resources lost in these critical events can be reduced. Numerous house fire prevention initiatives have been introduced in many communities around the world in an attempt to reduce fire morbidity and mortality. The most popular of these measures have included education and training of children, parents, and certain high risk populations such as the elderly, in both school and community based programs and the promotion of smoke detectors and sprinkler systems for home use, and smoke detector legislation. The effectiveness of these methods have been studied extensively [65] and it has been shown that methods prove ineffective for a multitude of reasons including ill-prepared material "program overload", lack of availability, lack of resources, amongst others.

Universities are an excellent example of the dangers of ill-preparedness. Although there are many labs and equipment on a university campus that can cause fires, there are only a select few who understand the proper safety measures to take, most of these being full-time staff members who work with such equipment. This would leave the thousands of students that walk in and out of a university building every day completely unaware of what to do when a critical incident actually occurs. Seemingly, the only thing left for a student to do when a critical incident occurs is to find the nearest sign and read it for instructions. However, these signs are not an effective way of educating. They often are overlooked until an emergency occurs, and in that case there is far too much text on the signs to add any benefit to a person who is currently undergoing the stress and pressure of an emergency procedure (see Figure 1.1).

There is also an equal amount of effort placed on fire evacuation techniques. With appropriate practice, fire evacuation techniques can lead to a reduction of evacuation times. As stated by the HRSDC, "Most fire fatalities are caused by asphyxiation from smoke - not by burns. Therefore, safe and efficient evacuation procedures are crucial in any fire emergency. For that reason, everyone must know what to do in the event of a fire" [82]. Training at large institutions, including universities, commonly involves fire evacuation techniques (commonly referred to as fire drills), a method of practising the evacuation of a building where evacuation times are recorded and problems with the emergency system or evacuation procedures are identified to be remedied. This typically requires involvement with the fire department and other such emergency response groups to assist in enacting a scenario of a critical incident and what their role would be. In addition, fire evacuation drills are either considerably disruptive when they occur unannounced or tediously uneventful if routinely practised [94]. There has been considerable work done on modelling human behaviour in response to fire events but detailed evacuation behaviour of individual building occupants can be somewhat unpredictable [57].

Prior training is necessary since stress in a real fire situation has been said to prevent creative thinking which is required in any level of improvised problem solving. Moreover, the combination of stress and lack of knowledge may lead to the "cognitive paralysis" phenomenon, where people do not take any action at all, leading to fatalities in otherwise survivable conditions [14]. When looking specifically at institutions and workplaces, where the number of participants required to train can range anywhere from the hundreds to thousands, we notice that the strategy employed to train employees is not just a question of effectiveness, but a financial matter as well. A training drill may be suitable for a workplace with no more than 50 employees, but that same training drill in an assembly factory may cause the disruption of machines, and thousands of workers to break away from their work leaving a lot of unfinished product, some even to waste. These costs can of course be negligible compared to the costs incurred during an actual fire, however it is still a deterrent when undergoing fire safety training for a mass audience. It is also important to realize that uneducated participants making bad decisions during a fire may cause more money and lives lost than if the fire had just been dealt with by someone who had knowledge of the proper procedures. For example, if a containable fire is spread, not naturally, but due to ill-educated practice (which may happen often in more complicated fires that involve chemicals), it can lead to greater risk of injury, even death, and far greater monetary costs than it would have if proper techniques were used.

Lack of proper fire preparation, typically within industries and large buildings with high capacity (e.g., universities and high schools), can lead to serious injury even death, and huge costs (property damage, time off work, etc.) [82]. Current fire preparation is inadequate, often training only a select number of employees or posting signs that may confuse or more likely be neglected in the wake of a fire emergency and therefore many complexes and companies are not prepared to handle fire emergencies.

How can we ensure improved fire response in a safe, cost effective manner that will motivate employees to take part? How can we distribute the educational program so all employees that need to be educated receive ample training? This thesis

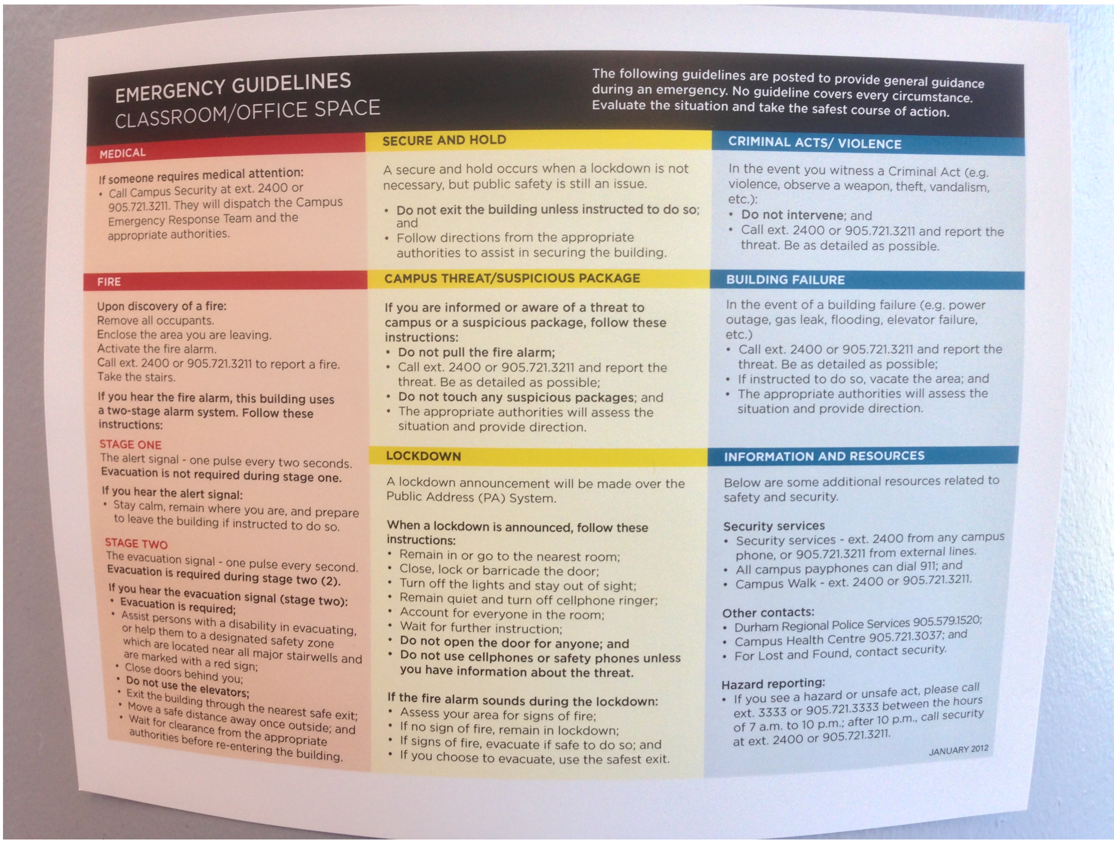

Figure 1.1: "Emergency Guidelines" posted throughout the hallways of all the buildings at the University of Ontario, Institute of Technology.

proposes a solution to this matter using video games technology, otherwise known as "serious games".

1.2 Serious Games

The rising popularity of video games has seen a recent push towards the application of video game-based technologies for teaching and learning. Virtual simulation and serious games can be an effective strategy for incidence response training as they offer a viable, economic, and safe alternative to the current training methods and techniques and are generally far more engaging than traditional training techniques. Although no particular clear definition of the term is currently available, serious games usually refer to games that are used for training, advertising, simulation, or education and are designed to run on personal computers or video game consoles [97]. They have also been referred to as "games that do not have entertainment, enjoyment, or fun as their primary purpose" [69] but be more formally defined as an interactive computer application, with or without a significant hardware component, that i) has a challenging goal, ii) is fun to play and/or is engaging, iii) incorporates some concept of scoring, and iv) imparts to the user a skill, knowledge, or attitude that can be applied to the real world [8].

Serious games "leverage the power of computer games to captivate and engage players/learners for a specific purpose such as to develop new knowledge or skills" [22] and with respect to students, strong engagement has been associated with academic achievement [92]. In addition to increased engagement and promoting learning via interaction, there are other benefits as well. They allow participants to experience situations that are difficult (even impossible) to achieve in reality due to factors such as cost, time, and safety concerns [92]. Serious games support the development of various skills including analytical and spatial, strategic, recollection, psychomotor skills, and visual selective attention [71]. Improved self-monitoring, problem recognition and solving, improved short-and long-term memory, and increased social skills have also been attributed to serious games [71]. Another term sometimes interchanged with serious games are educational games. If serious games are to be defined as any game that does not have entertainment as its primary purpose [69], than an educational game is any game whose purpose is primarily education.

1.2.1 Issues within Serious Games

Although serious gaming is being pushed forward by many different groups and organizations, there is still no solid formula for what makes a good serious game. Many serious games have been dismissed for their poor game design, and lack of instructional design, and often prove more ineffective than the traditional learning method that the game was intended to replace. This is often credited to a deep-rooted misunderstanding of how serious games, and more specifically, educational games, should be utilized. This can be partially attributed to an earlier generation of educational games that did very little to differentiate themselves from teaching strategies such as a quiz, and simply provided the same learning opportunity but on a digital screen. This era is commonly referred to as the "edutainment" era, and refers to a time in the late 80's and early 90's where the majority of educational games created lacked instructional design, however the demand for educational games continued growing [42]. Debates as to whether interactive media are inherently conducive to education [16, 58] are still ongoing. However, it is agreed upon that the simple presence of educational content in a game does not guarantee effectiveness. Rather, the educational power of any such game also depends on a variety of other factors [37]. More specifically, the educational content must be sound, age-appropriate, and presented clearly [36], the interface must be easily usable by the target audience [67], and the educational content must be well integrated into the game. Although the research literature on the effects of serious games is still relatively young and may not prove whether or not serious games are more effective than traditional methods, (however it has been suggested that they may be [116]) serious games still point to a good alternative to traditional methods for other reasons (when it makes economic sense due to the amount of learners [54]).

There have been many attempts to create frameworks which should produce effective serious games ([29], [30], [109]), however at this point all those proposed frameworks are still preliminary and have not proved their competence. Their may in fact be no specific strategy to create an effective serious game, however there are many unresearched areas in the field that can greatly improve the chances of the created game to be effective within a particular learning group.

One area that seems to be left open is the question of fidelity [100] especially in the medical training field. Some professionals in their respected fields state that the issue with serious games may be the fact that serious games offer insufficient fidelity to be of any use in actual training [121]. However, on the opposing side there is an argument that situated learning (whereby the learning environment is modelled on the context where the knowledge is expected to be applied) can be replicated in a virtual environment far easier than the traditional learning approach [26]. Ruzic states that "the advantages of VR-based teleteaching are individualized, interactive and realistic learning that makes virtual reality a tool for apprenticeship training, providing a unique opportunity for situated learning" [85]. Discovering the relevant fidelity levels that allow for effective training would be a progressive step towards creating effective serious games.

There is also the question of the type of interaction we can have with serious games. The interaction techniques may be just as important in some cases as the content of the game, since they can effect immersion, presence, engagement and ultimately, learning, Some modes of interaction can increase engagement in the content, as well as simplify the interface in which the player uses to play the game. Recent strides in interaction research have created technologies that promote innovative interaction possibilities. An example of this is the Microsoft Kinect, a consumer-level product that allows for motion input (e.g., hand gestures) to replace keyboard-and-mouse input. It has been suggested that a more natural input device will allow for a more engaging experience, and that the button input device (defined as anything that requires pressing a button, such as keyboard and mouse) will one day be entirely replaced [76]. Natural interfaces can deal with actual human motions in real time as opposed to a button interface which forces a user to translate a button press to a natural motion which may be ineffective (e.g., pressing a button to have your character/avatar jump in a game). "Presence", defined as the subjective experience of being in one place or environment, even when one is physically situated in another [114], can be increased when using a more natural interface [33], however increased presence does not necessarily lead to increased engagement, and although there are works suggesting that natural interfaces can create engaging content [1], it is not confirmed whether that level of engagement is more than the level you would receive interacting with a traditional input device such as a keyboard and mouse (although it has been predicted by experts in the field [76]). This final piece of research would be vital for the discussion on whether natural input devices should be used within serious games, since engagement has been proven to increase academic achievement [92].

Among new input techniques that technology is allowing for, is the development and recent accessibility of stereoscopic 3D imaging techniques. With the availability of consumer-level stereoscopic 3D displays, 3D capabilities are undoubtedly becoming more accessible in the simulations and training sector. While the technology of stereoscopic displays and content generation are well understood, there are many questions yet to be answered surrounding its effects on the viewer. Effects of stereoscopic display on passive viewers for film are known, however serious games are fundamentally different since the viewer/player is actively (rather than passively) engaged in the content.

With respect to medical education and training, it has been suggested that the use of stereoscopic 3D can i) lead to improved understanding of anatomical relationships and pathology, ii) improve the quality of the student's learning experience, and iii) create more life-like training simulations [72]. Furthermore, stereoscopic 3D provides the ability to establish foreground and background information [47], which can be useful in a variety of training situations. However, the technology can also be problematic, as it may lead to participants "hyper-focusing" on the foreground while ignoring potentially important information within the periphery [47]. Therefore, the usefulness of stereoscopic 3D for training simulations and serious games needs further study.

Despite the potential benefits, there are few serious games that employ stereoscopic 3D viewing and only a limited number of studies have been conducted that explore the effect of stereoscopic 3D in a serious gaming environment. Several preliminary studies have shown that stereoscopic 3D viewing facilitates players' engagement in the gameplay [46].

1.3 Purpose of this Work

Given the importance of incidence response preparedness and the issues associated with incidence response education and training (e.g., high cost, scalability, ineffectiveness, etc.), it was decided to leverage the benefits of serious games by investigating the development of an interactive serious game for the purpose of incidence response procedure education and training. Realizing that incidence response training is such a vast area, it was decided to focus on only one protocol.

A chemical lab environment has many inherent hazards, which can easily affect not only lab members but those outside of a lab especially in a university campus setting. "Flammable liquids, compressed gases, oxidizers, and a lengthy list of other chemicals can prove to be deadly in the event of a laboratory fire. The best defence against these hazards is prevention and safe operating procedures" [74]. At a university level it may be very common for those procedures to go untaught, and in some cases even those working in a lab may not have received proper training. Also, the training techniques currently in place (such as online quizzes) are outdated and can be very ineffective depending on the learner, since it completely neglects a situated learning model [65]. Based on these issues associated with chemical lab safety training, it was decided to create a game whose purpose was to teach about chemical lab fire safety.

The chemical lab fire safety game was developed and used as a test-bed to investigate user performance issues in an incidence response training game. The game was developed solely by the author of this thesis. However, 3D models used in the game (e.g., the avatars, lab furniture, and fire extinguisher, amongst others) were developed by others. The purpose of the game is to provide instruction on evacuation techniques that are standard practice and should be taught to all chemical lab instructors, who in most cases are the designated fire marshals who carry out the proper protocol. The game allows the player to experience multiple scenarios and play through those scenarios as they would in real life. Feedback is provided on an ongoing basis letting the user know that they are doing well when they follow procedures correctly or letting them know when they have made an error while providing them with information regarding the error and how to correct it. It has also been proposed that the use of alternative viewing techniques, such as stereoscopic 3D may be conducive to learning [61]. However, there are also many issues that arise in stereoscopic 3D games, and little is known of its impact on a serious game. Therefore, in addition to the instructional value of the serious game, in this work it is also being used as a "test-bed" to examine and answer various questions pertaining to user performance with respect to stereoscopic 3D viewing.

With the assumption that knowledge can be transferred from a serious gaming environment to real life situations, then it can be hypothesized that greater user performance in that gaming environment will lead to a better performance in a real life situation as long as the game scenario entails a careful amount of similarity to the real life scenario. This bridge between performance in a serious game and performance in real life still remains an open question. However, there has been research pointing to the positive effects serious games may have on the user when they are placed in the same environment the game had trained them in [71].

Spatial awareness is where a person maintains an awareness about a specific place and can monitor what is happening there [3], and can be an important focus of learning for certain tasks, especially if one is able to retain that knowledge. One of the most common factors that require spatial awareness in fire safety, is the appropriate distance to remain from a fire at all times, especially when using a fire extinguisher [86]. When extinguishing a fire, standing too close may risk burns and other fire-related injuries, however standing too far may be an ineffective use of a fire extinguisher. Extinguishing a fire is also an extremely expensive scenario to replicate in real life, so teaching it within a game may be of economic benefit. With the assumption that serious games may effectively be used as teachers of spatial awareness as studied by Mitchell and Savill-Smith [71], then one can use a serious game to teach important spatial relationships in an emergency procedure in hopes that participants will retain that knowledge.

New open areas of research in serious gaming such as stereoscopic 3D imaging may show an increased impact on spatial learning patterns and knowledge retention in a training game. This increased retention when using serious games can lead to more effective games and training applications which will ultimately lead to better training of personnel in general. Effective serious games may also lead to the use of games instead of high-cost training programs.

1.3.1 Studying the Effects of Stereoscopic 3D

Although training games and simulations have been thoroughly researched, we plan to explore the use of stereoscopic 3D viewing techniques to judge whether they would be effective for us in the fire safety training game. Three factors will be looked at in this thesis: i) engagement in stereoscopic 3D, ii) calibration settings of stereocopic 3D games, and iii) knowledge retention in stereoscopic 3D.

The first study examines user engagement in stereoscopic 3D. The study examines user engagement levels of a game played in stereoscopic 3D with the same game when it's played in traditional 2D. This study was conducted by the author of this thesis in addition to two fellow classmates which are all referenced in the same publication [46].

The second study examines issues with calibration of stereoscopic 3D settings. The study proposes a new interactive calibration method to aid the user in the proper selection of stereoscopic 3D settings. The calibration method and the study involved was developed and conducted by the author of this thesis.

The third and final study employs the fire safety training game as a test-bed to examine user performance and knowledge retention in a spatial awareness task, that can be translated to it's real life counterpart. This study was conducted by the author of this thesis.

Using the game as a test-bed, the final study will examine the effects that stereoscopic 3D viewing has on user performance and knowledge retention within a serious game setting and more specifically, within a fire simulation where the user must extinguish the fire. This will be compared to the same game played with traditional viewing techniques. The task examined here is extinguishing a fire, which requires a level of spatial awareness since the user has to extinguish the fire from a safe yet effective distance. This task will be used to test whether participants retain knowledge more accurately when they were trained in either traditional 2D viewing or stereoscopic 3D viewing. The current literature suggests that stereoscopic 3D viewing will improve user performance when the task being performed involves, or relies, on the depth axis, where the success of the player is based almost entirely on depth information and whether it was learned properly [61]. A study designed to investigate user performance in S3D vs traditional viewing techniques is developed in this thesis. The study will also investigate learning effects that S3D has on a participants' ability to retain knowledge.

The three studies presented in this thesis were not performed consecutively. Rather, there was a few months separating each study. Participants were also not necessarily the same in each study, however some participants were present in more than one study.

1.3.2 Hypothesis

In this thesis it is hypothesized that a stereoscopic 3D viewing environment will result in a greater engagement and learning than in traditional 2D viewing methods, when playing the fire safety training game. Particularly in the third experiment, in which the user must extinguish a series of fires from a safe distance, we hypothesize that the individuals who learn the appropriate distances in stereoscopic 3D will perform better when asked to replicate those same distances in both viewing modes the next day.

1.3.3 Thesis Structure

The remainder of this thesis is organized as follows. In Chapter Two, a background/literature review is provided. An overview of serious games is provided, including training games, incidence response training games, and motor rehabilitation games. The games discussed in this chapter have heavily influenced the chemical lab fire safety training game developed in this thesis. In addition, an overview of stereoscopic 3D technology is provided, specifically pertaining to stereoscopic 3D displays, depth cue theory, and a review of the use of stereoscopic 3D technology within the realm of video games. A literature review on stereoscopic 3D studies is also included which provides background information behind the studies conducted in this thesis. The fire safety training game is described in detail in Chapter 3, where information regarding the development of the game and how the game is played is provided. Chapter 4 describes the first study conducted to investigate engagement effects when playing a game in stereoscopic 3D as opposed to playing a game in traditional 2D. Chapter 5 describes the second study which investigated user calibration techniques for a stereoscopic 3D video game. Chapter 6 describes the third and final study which investigated knowledge retention and user performance directly within the fire safety training game. The results of all the studies and their implications are discussed in Chapter 6 along with concluding remarks, and plans for future research.

Chapter 2

Related Work

2.1 Serious Games

Serious games are games that are used for training, advertising, simulation, or education and are designed to run on personal computers or video game consoles [97]. Serious games have also been defined as games that do not have entertainment, enjoyment, or fun as their primary purpose [69] but may more formally be defined as an interactive computer application that i) has a challenging goal, ii) is fun to play and/or engaging, iii) incorporates some concept of scoring, and iv) imparts to the user a skill, knowledge, or attitude that can be applied to the real world [8]. There is often a misunderstanding between serious games, games and (virtual) simulations, and there have been multiple bodies of work attempting to explain the relationship. Although (virtual) simulations and serious games are similar, all serious games are games, and all games are simulations [5]; (see Figure 2.2) and can employ identical technologies (hardware and software). A study by Johnston et al. attempts to explain the differences between the terms. In this work they present a means to segregate the three on the basis of user intent and the closeness to their reality, rather than the intent of the designer [51] (Figure 2.1). They argue that this categorization provides a number of advantages, particularly in defining the ideas of games vs. serious games vs. training simulations with respect to an educational situation.

Serious games have become more frequently in demand as the rise of the millenial students, sometimes referred to as digital natives, takes place. Today's students represent the first generation to grow up with such a high involvement of digital media. The average college graduate today has spent less than 5,000 hours of

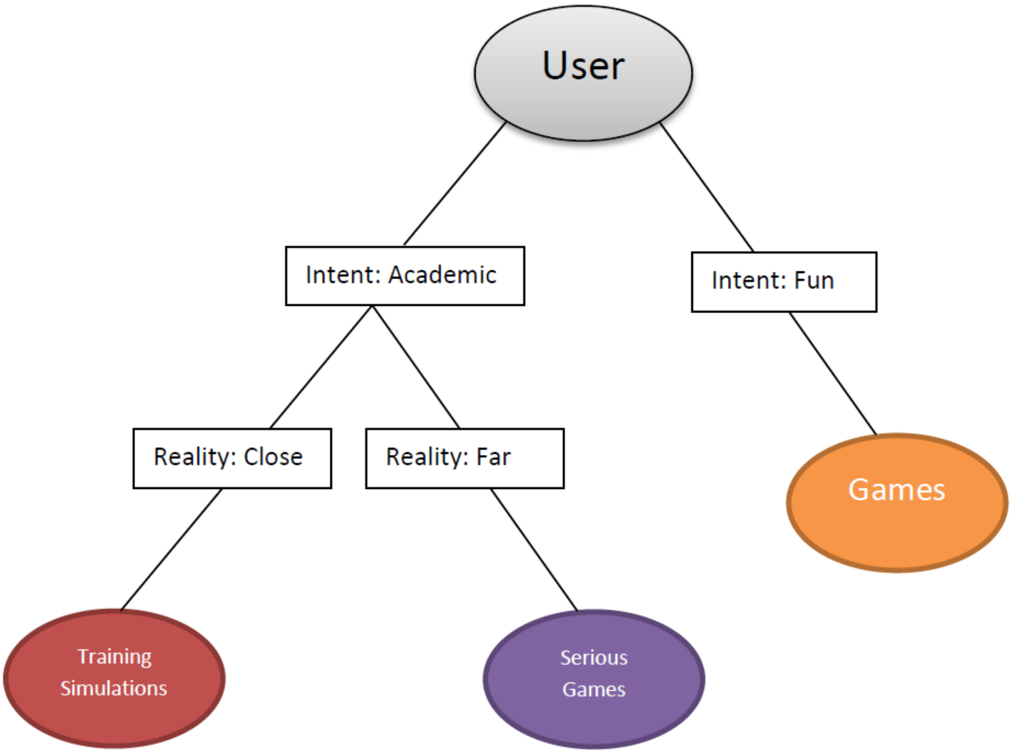

Figure 2.1: "Classification of Serious Games" by Johnston et al. attempt to explain the difference between serious games, games, and simulations [51].

Figure 2.2: "Classification of Simulation Games" by Becker et al. show that all simulation games are games, and all games are simulations [5]. In this case simulation games are synonymous with serious games.

their lives reading, but over 10,000 hours playing video games [78]. Computer games, email, the Internet, cell phones and instant messaging are integral parts of their lives. Due to the sheer volume of interaction with all of these new digital media, today's students think and process information fundamentally differently from their predecessors [78]. This can be attributed by the brains ability to change with new input, which is why it is widely accepted belief that teaching millennial students (digital natives) require a different approach to education than that of other generations [66]. At the forefront of these new education techniques are serious games and educational games.

Corriveau et al. conducted a study using game environments, such as Second Life, to create a teaching centre for a university course on business strategies [21]. The study reported that having students challenged to demonstrate their understanding of the teaching material through the creation of animations constitutes a novel approach to the evaluation of students, one that favours student engagement and collaboration. Another advantage provided by educational games is their mobility and portability. Since games are in a digital form, they are economical and easy to distribute creating a wider access to education. Educational games can be placed on nearly any technological device- from a mobile phone, to the internet- games can be distributed far more efficiently and effectively than any other learning material. Not only are students given the ability to access the material anywhere as long as a capable device is with them, they are also able to access the material at any time, allowing for geographical limitations of education and teaching to decrease. An example of this was seen in a game which was used to teach literacy for rural children in India [54]. By providing the game on mobile phones the game can be made available to children who can't afford proper schooling but do have access to mobile technology. They have demonstrated the ability to achieve a good balance between pleasure and learning, to the extent that learners exhibited improved results on test scores on the material presented to them (see Figure 2.3). There are many other similar success stories regarding the use of serious games within an educational setting but in general, the effectiveness of serious games however is at times debated ([45], [40]).

Although there is still not enough data to present a solid case for how effective serious games are and greater work remains, Wong describes a comparative study that thoroughly investigated the effects of interactivity and media richness on science learning among college students [116]. The conclusion of the study suggests that the processing of factual knowledge can be intensified through the motivational impact of entertainment. Other work has examined the effectiveness of serious games and how fun can be used to promote learning and health awareness. A study was conducted [96] which explored adolescents' technology usage, gaming habits and gaming motivations as well as the elements affecting the user experience in a serious game. The case study revealed the importance of social applications in a serious game as well as 'games' connotation of being both a fun and relaxing environment, which can be used effectively to teach in. A study by Livingston et al. evaluated over seven years of research and over 150 studies examining the effectiveness of gaming [17]. It was concluded that although serious games were able to teach factual information, they were not necessarily more effective than other methods of instruction. That being said, it was observed that students preferred serious games over other classroom activities, and participation in these serious games can lead to changes in their attitudes toward education, career, marriage and children. A more recent literature review conducted by Connolly et al. identifies 129 papers reporting empirical evidence about the impacts and outcomes of games, including a critique of those cases where the research methods performed were not adequate [10]. They found that playing computer games is linked to a range of impacts and outcomes including knowledge acquisition/content understanding and affective and motivational outcomes.

Serious games are becoming a popular option to educate and train individuals. Klopfer et al. outlines the reasons why serious games are beginning to dominate the educational landscape [49]. They describe "the role of play" and explain how it must exist in an effective learning environment, whether it be a traditional classroom, or a handheld games. This idea is very much in line with Marshal McLuhan, the great Canadian educator, philosopher and scholar, who once stated that "anyone who makes a distinction between educational and entertainment doesn't know the first thing of either one". Klopfer et al. go on to state that the state of play presents the learner with five freedoms that all easily exist within serious games these days: i) freedom to fail, ii) freedom to experiment, iii) freedom to fashion identities, iv) freedom of effort, and v) freedom of interpretation. These freedoms are easily given to a user within a game and are easily outlined [49]. A player's freedom to experiment is only limited by the complexity of the game, and their freedom to fail is much easier and more comfortable for a user to perceive within a game as opposed to real life (which can arguably be both beneficial and detrimental). However, whether games clearly provide these freedoms, more clearly than most traditional learning environments, cannot be argued any more.

Serious games development is an interdisciplinary process, bringing together experts from a variety of fields including game design and development and although

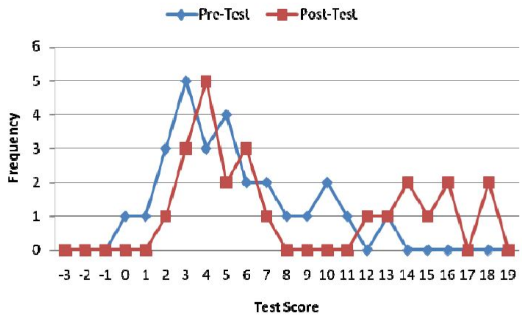

Figure 2.3: Pre-test and post-test scores after distributing a mobile game in rural India to help teach literacy [54].

serious games designers are not expected to be experts in instructional design and the specific content area, possessing some knowledge in these areas will, at the very least, promote effective communication between the interdisciplinary team members [55]. There has also there has been a push towards a model-driven framework, designed to aid non-technical domain experts in the production of serious games [99].

2.2 Using Serious Games for Training

Serious games are being used for training in both the academic, and the commercial (non-educational) sector. An example of how the non-educational industry can make use of serious games is provided by Curtin et al. and their study of web-based learning games to reinforce the training program of an IT help desk [23]. This study explained that by using training games, they can increase morale and liven up the entire office while giving a significant boost to the existing training programs. This opens up serious games to a much broader field, and its application is no longer strictly within the academic sector. Serious games have also been used to train teachers, as seen by the creation of the game, "Teaching Game", that explores the possibility of creating a simulation of a classroom event in the format of a game [9]. Bouki et al. state that the study conducted to examine the effectiveness of the use of their game successfully demonstrated that games can be used to re-create work environments and to create scenarios within those worlds that the user can learn from [9].

When creating training scenarios, often games fail when considering the fact that the scenarios become too repetitive. A study conducted recently by Lopes presents us with evidence to support the idea of flexibility in serious games [64]. Lopes states serious games are currently too predictable and this can be a detriment to the learning experience, since the game becomes a stereotyped repetitive experience. By using a new semantic modelling method, an instructor can teach the user what to learn, how to learn, and what went missing by implementing pre-game scenarios, in-game events, and post-game scenarios respectively. The inflexibility of serious games can be a detriment in the education and effectiveness of a training game [64]. Another area of research that pertains to making effective serious games, is the area of fidelity and realism. Tashiro and Dunalap describe an evidence-based model for improving the quality of games and the outcomes of game-based instructional methods for K-12 and undergraduate science courses [100]. More importantly, they also explore the impact of realism and engagement in instructional games and simulations within the context of creating an evidence-based framework for teaching, learning, and assessment of learning outcomes. Although the evidence of their study provides no concrete data of how much realism is appropriate, they do discuss the extensive use of educational models to study the impacts of realism and engagement.

One of the fields that is beginning to employ serious games is the area of e-Learning. An example of serious games used in e-learning is seen in a study that examined cognitive/instructional design principles and serious gaming learning effectiveness issues that may explain why people spend hours of their time playing computer games [41]. They reported the assessment of the relative complexity of a game-based training environment for cyber security education and training (CyberCIEGE) and possible enhancements based on that perspective.

Attention cueing is another problem area when creating serious games for training. To experiment with this problem, a game was developed by Van et al. that was able to discuss the problems with developing a game that is cognitively demanding, since novices may fail to distinguish between relevant and irrelevant information [103]. Van et al. discovered that by subtly cueing the players attention to the material most relevant, the player would have higher chance of completing the associated tasks [103]. However, it must be noted that when examining the effects of subtle auditory cues, they received the same results as the control group, signifying that the cures must be obvious to a degree, or they will be overlooked.

Figure 2.4: Participants playing a paper-prototype of a card game that was meant to evaluate and train group decision making skills by allowing players to mimic a real-world emergency response team [63].

2.3 Serious Games for Incidence Response Training

Incidence response training has been of specific interest to serious game designers, and alternative educators in general. Although incidence response training is critical, it is often very difficult to deliver proper education to a mass audience, and as a result, the negative effects are only seen when it is too late (typically when an incident occurs and uneducated workers respond inadequately), it is often neglected. This makes it a perfect platform for the development of serious games, since serious games can provide more effective options for mass distribution as well as more engaging ways to teach participants. Linehan et al. describes the development of a non-virtual serious game [63]. They created a paper-prototype of a card game that was meant to evaluate and train group decision making skills by allowing players to mimic a real-world emergency response team [63](see Figure 2.4). The game design proved to be a valid environment in which to train, practice, and evaluate the decision making behaviour of groups and function as a valuable and engaging part of a group decision making skills training course.

There have also been plenty of virtual serious games created for the intent of incidence response training. Smith et al. developed a serious game by using the Source game engine, popularized for creating many successful commercial entertainment games [94]. This is of particular interest since they describe how the use of commercial game engines (which are designed to help the development of commercial entertainment games) can shorten the amount of time it would take to create a

Figure 2.5: The Sidh game environment [2].

prototype for a serious game. They also discuss many inherent problems of keeping the game unchanged from the popular commercial games that were made using the same engine, to ensure familiarity with controls, unrealistic expectations, etc. It is important to understand a participant's expectations when playing a game that looks similar to a game they've already played, since if the expectations are not matched, this can frustrate the player due to unfulfilled expectations. There are also many other emergency evacuation games which present the same results with little change of technique, such as those reported by Van der Spek et al. [103], and Chittaro et al. [14].

Backlund et al. developed "Sidh", a game based fire-fighting training simulation that has been used to train fire-fighter students [2]. Sidh utilizes a virtual reality "CAVE", which allows the user to move freely inside a small room surrounded by screens, and their interaction with the game is recorded by a set of sensors (see Figure 2.5). Players move in the virtual world by movements in the physical world and a substantial physical effort is required to accomplish game tasks (such as being forced to walk more physical steps if carrying a heavy object). A feasibility study demonstrated that Sidh is a useful complement to traditional training methods and received high grades on the entertainment value of the game which indicate that this form of training may be self-motivating, which would allow participants to work after-hours enjoyably.

The virtual environment itself also becomes a key factor when training firefighters for emergency scenarios. Ruppel et al. have proposed a virtual training environment for firefighting, which combines Building Information Modelling (BIM) with all the aspects of a virtual training simulations [84]. With BIM, all information is available to create the virtual environment from the physical environment that a firefighter would need to train for (see Figure 2.6). Aside from academia, there also exists substantial commercial software which is used for fire safety training. Fire Studio is a professional software tool that allows you to create simulations for fire,

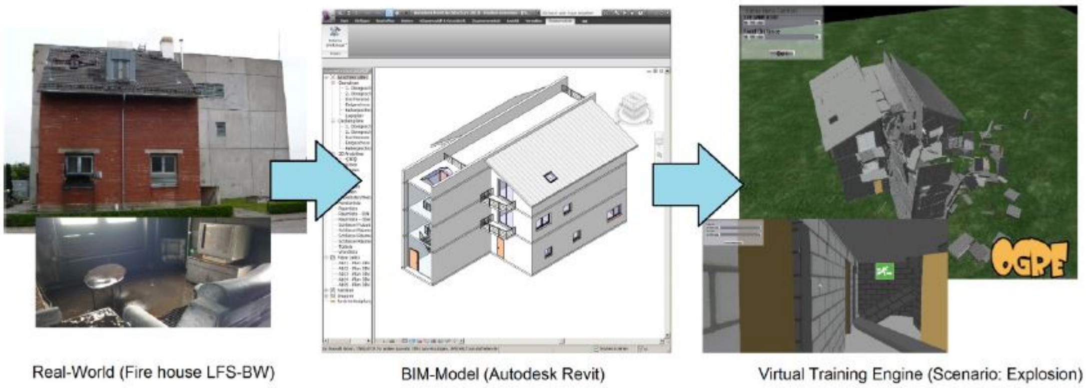

Figure 2.6: Using BIM information, a real-world environment can be used in a virtual simulation for fire emergency training [84].

Figure 2.7: Fire Studio 5 allows you to import custom pictures and create videos from them to mimic emergency situations such as fires [18].

hazmat, and other emergency simulations [18]. By importing photos, participants can create emergency situations which display on the photo itself (see Figure 2.7).

Tactical Commander 2 (TCT), a game released in 1997, has become the development and assessment tool for over 85% of UK fire and rescue services and 100% of Australasia's services [19]. TCT claims to be an "advanced, industry-leading virtual reality/3D and artificial intelligence-based training system for fire incident commanders which is not only highly effective and intuitive to use but has been proven in many fire and rescue services around the world" [19]. TCT works by putting participants, primarily firefighting personnel, in different 3D scenarios (there are over 50 unique scenarios at this time) which were developed in conjunction with leading fire, rescue and emergency services in the UK, the USA, Europe, Australia, New Zealand, and the Middle East (see Figure 2.8).

Figure 2.8: Tactical Commander 2, a 3D scenario-based training game, has become the development and assessment tool for over 85% of UK fire and rescue services and 100% of Australasia's services [19].

However, serious games are not limited to fire evacuation, as demonstrated by a group of researchers who have created a prototype to develop skills in emergency medical support nurses [106]. This game was chosen specifically due to the usual reluctance of nurses to adopt new technologies for education. Results suggest an overall acceptance of the game. This work is significant since it demonstrates proven methods of gathering information from a direct user base that will be using the game for its intended purpose.

2.4 Serious Games for Motor Rehabilitation

Motor rehabilitation is another section that serious gaming is beginning to penetrate. A great demonstration of this is a game that attempts to target the rehabilitation of patients with chronic pain of the lower back and neck [89]. This is an accomplishment through the use of a full body motion capture system, which together with a biosignal acquisition device has been integrated in a game engine to train the player's motor skills in a serious game. The players displayed a positive trend of decreasing pain intensity score and disability scores and an increase on walking distance after a gaming / training period of four weeks. The results have been promising which demonstrates the use of external technologies to reach audiences that could not have been reached otherwise. Another study conducted by a different group also demonstrates a similar game that attempts to help the visually impaired develop a greater understanding of pointing [75]. These two examples illustrate that serious games can be used to train individuals, not just with respect to cognitive sills, but also with respect to motor skills.

2.5 Stereoscopic 3D Technology

Stereoscopic 3D (S3D) technologies are becoming widely adopted at the consumer level for entertainment purposes. However, they have yet to be adopted in the professional sector at a large scale, even though there are many potential benefits to using the technology, such as effective distribution, increased engagement in content— and more often than not— cheaper content creation. When examining the medical industry specifically, arguably the most demanding field for serious games and training applications, broad acceptance and uptake of new technologies will only happen if clear, quantifiable advantages can be demonstrated, either in the quality of patient care and/or in terms of significant cost savings [102]. This dilemma can be expanded to any domain looking to leverage new technologies to aid in creating effective services and training programs. If stereoscopic 3D was to be adopted on a large scale, it must not merely provide a benefit, but the value added must surpass all the negative implications of adopting a new technology, such as re-training individuals, re-designing entire infrastructures, amongst many other obstacles that would impede the acceptance of a new technology.

2.5.1 Stereoscopic 3D Displays

Stereopsis can be defined as the perception of relative depth that derives from binocular vision [91] and is a powerful depth cue, particularly for objects that are relatively close to the viewer [118]. It is computed implicitly by our human visual system using separate images from both eyes which creates a disparity between the two images based on the unique viewing angles and positions of both our eyes. In order to recreate a stereoscopic effect, separate unique images must be presented to both the left eye and the right eye, which is of course challenging when using a traditional display.

Stereoscopic 3D displays attempt to leverage the stereopsis phenomena by creating a viewing technique (which dates back to the invention of the first stereoscope by Sir Charles Wheatstone in 1838 [110]) which allows for the individual viewing of a left eye image and a right eye image by each of our eyes respectively. Many techniques have been pursued by hardware manufacturers to separate these images

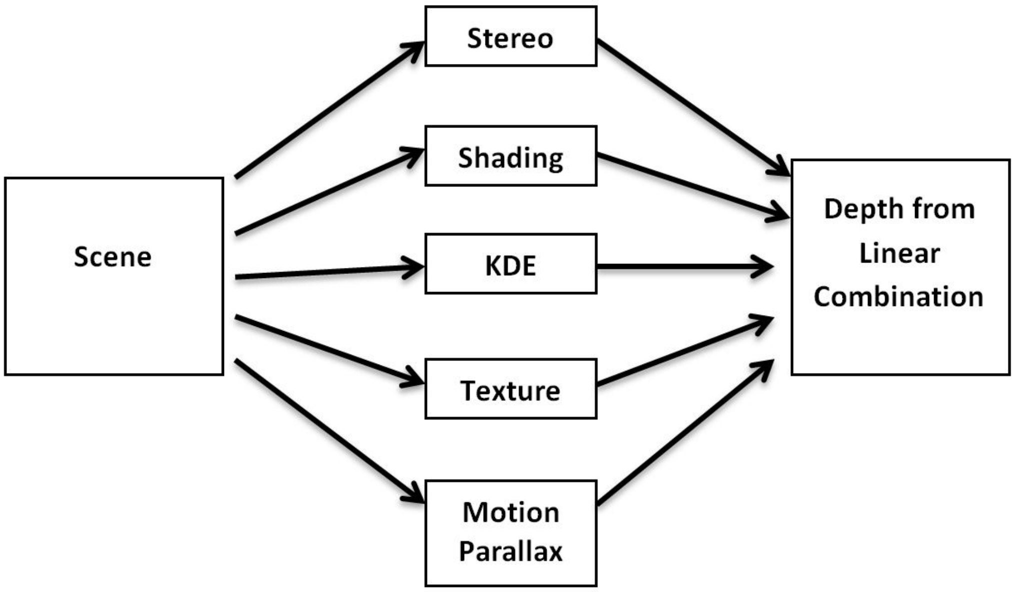

Figure 2.9: The weak fusion model: Each depth cue is processed independently, these estimates are then combined linearly [60].

and present them to each eye individually using displays known as Stereoscopic 3D displays. The addition of a binocular cue, when otherwise not present, introduces many questions regarding the effectiveness of the binocular cue. The attempt to answer whether or not stereopsis does in fact add important depth information can only be understood upon reviewing the current literature dealing with depth cue theory.

2.5.2 Cue Theory

Cue theory suggests that the visual system implicitly computes the distances of environmental objects on the basis of information about the posture of the eyes and patterns of light projected onto the retinas [48]. Various visual cues provide information about depth and shape in a scene. The most commonly exploited depth cues include occlusion, perspective, shadows, texture, stereopsis, motion parallax, and active movement [120]. When several of these cues are simultaneously available in a single location in the scene, the visual system attempts to aggregate them, although how they are actually aggregated is still heavily debated [60]. The visual system may attempt to combine these cues, or ignore some cues in favour of others. This problem of combining visual cues is often referred to as the sensor fusion problem [60].

There have been many models that attempt to explain how these depth cues are combined but it is still under debate which model is the most accurate. Three models have been at the forefront of the dialogue when attempting to explain the cue combination problem. The first, and most simple model is known as the "vetoing" model. In this model, the stronger cue simply veto's the weaker cue provided in a scene [50]. An example of this can be taken from Bulthoff and Mallot's work in which they studied stereopsis and shading cues and found that when stereoscopic indicates a flat surface but shading indicates an ellipsoid, no significant depth is perceived, which demonstrates that when stereoscopic cues were present the human visual system attempts to ignore other weaker cues [13]. In simpler terms, the experiment proved that the stronger stereoscopic cues can "veto" the weaker shading cues [13]. In 1990, Clark and Yuille proposed two other models to attempt to explain the sensor fusion problem, the weak fusion model and the strong fusion model [15]. The weak fusion model (also referred to as a weighted linear combination) assumes that even when multiple depth cues are presented simultaneously on a screen, each of those depth cues are still processed independently, and depth estimates are then combined at each location by a rule of combination. This rule of combination works by first separating the estimates of depth which are given by different cues in isolation, and then to average the separate depth estimates from each cue to obtain an overall "depth map" for the scene [60] (see Figure 2.9). There have been many studies that have attributed the results of their experiments to a weak fusion model, finding support for a linear cue combination rule to many depth cues such as: stereoscopic, perspective, and proximity luminance [32]— motion parallax, occlusion, height in the picture plane, and familiar size [24]— and motion parallax and stereoscopic [83].

The strong fusion model was discussed in the same book by Clark and Yuille, and instead assumes that multiple depth cues are processed cooperatively to arrive at a single depth estimate [15] (see Figure 2.10). "Promotion", an instance of this model, as discussed by Landy et al. where the incompleteness of one depth cue is compensated for by another cue which provides information needed to yield independent depth estimates from the incomplete cue [60]. Disambiguation also exists within the strong fusion model. It can be observed in scenes where a depth cue may be ambiguous (such as kinetic depth) but information from another depth cue can be used to determine which of two potential interpretations is correct [32].

Stereopsis has always been understood as an effective independent depth cue as was demonstrated by the Julesz random-dot stereogram [53], and has proven to be a powerful cue because of its precision and the fact that it does not require

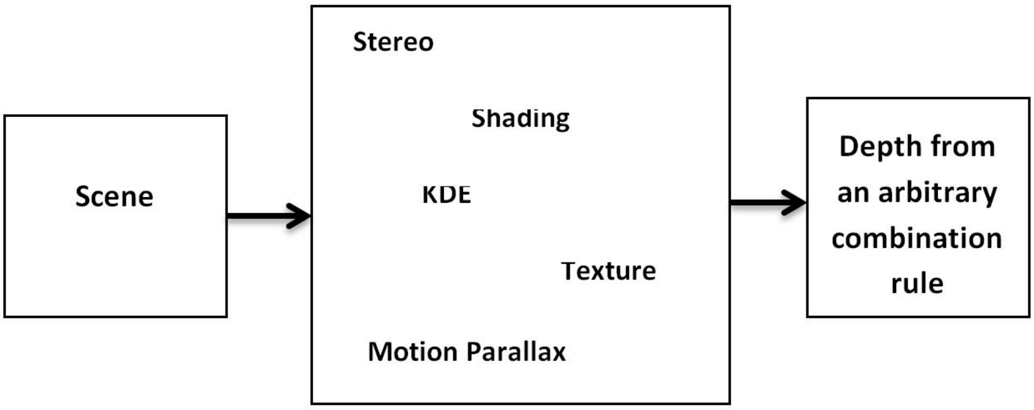

Figure 2.10: The strong fusion model: Depth cues may interact with each other, and the combination rule is not necessarily linear [60].

knowledge of surface properties to be an effective cue. At the basis of all these studies and the attempt to create an accurate model of our visual system, is the question of whether stereopsis does indeed affect our depth perception at all. If we were to abide by vetoing theory, it may be valid that stereopsis can be vetoed if other dominant cues are present. Using a strong fusion model, adding stereopsis will not necessarily provide the user with more accurate depth perception. Many studies have attempted to determine the direct impact stereopsis has on the user by measuring performance tasks in a stereoscopic 3D environment.

2.5.3 User Performance Tasks in Stereoscopic 3D

Stereoscopic 3D (S3D) and the affect it has on participants has been studied for many years. How it affects our depth perception is of huge importance and has therefore been studied to a large degree. Much of the current literature on user performance within an S3D viewing environment focuses on simple, isolated tasks in virtual environments, and there has been very little research involving more complex tasks that would be found in games. A recent study showed that viewers perceived static S3D images as well as moving images closer than they actually were and it was shown that the size of an image relates to that over-estimation of depth [98]. More accurate predictions of depth are made by viewers when they observed images with larger reference disparity (more depth), although it was stated that "the benefit of larger reference disparity was likely due to the longer spatial exposure of the visual trace, which provide more samples along the way for better estimation" [98]. This is contrary to what was proposed by Jones et al. previously that state there is an under-estimation that occurs in virtual environments in general, including those enabled with S3D [52]. However, much of those studies involved a head-mounted display (HMD), as opposed to a traditional monitor as in the study conducted by Tai et al. [98]. It was proposed that stereoscopic viewing in head-mounted displays were the reason for this under-estimation, but research has shown that it is not stereoscopic-viewing that causes this under-estimation, but rather the ergonomics of wearing an HMD itself [113]. The over/under-estimation of depth plays an important role in the adoption of S3D for training. However stereopsis is only one cue among many others, most of them being monocular, that help provide us with spatial information.

Monocular cues such as shadows, motion, size, etc. work alongside stereopsis to give us depth information about our scene. However, stereopsis is a more effective cue than shadows when determining the relative size and position of objects in space [48]. Hubona et al. conducted a study to determine how spatial information about the relative position and orientation of objects are perceived when looking at computer-generated graphics [48]. This study also pointed towards the vetoing and strong fusion mechanisms of visual cue theory to explain the dominant stereopsis cue. The participants were asked to perform two tasks with 3D geometric patterns of objects presented on a computer screen: i) positioning the object to complete a symmetrical geometric figure (see Figure 2.11), and ii) resizing the object to match the size of other objects (see Figure 2.12). Performance accuracy and speed were recorded under the four conditions: i) objects casting shadows on and off, ii) shadows from one or two light sources (nested within the shadows on condition), iii) stereoscopic and monoscopic viewing, and iv) different scene backgrounds: flat plane (i.e. floor); 'stair-step' floor with no walls; and floor with walls (i.e. room). While viewing objects in stereoscopic 3D, adding two shadow-casting lights actually degraded the task performance (in terms of both speed and accuracy) of the participants, which is contradictory to what is suggested by a weak fusion model, where the shadows should have increased task performance. Stereoscopic 3D can also be influenced by cues other than visual cues. In a study by Rojas et al. sound was shown to influence the perception of visuals with respect to stereoscopic 3D [25]. More specifically, similarly to monoscopic viewing, white noise led to a reduced visual fidelity perception while classical and heavy metal music can sometimes lead to an increase in visual fidelity perception (although this can be rather subjective) [25].

In a study by Bennet et al. stereoscopic cues were found to allow for richer memory experiences in virtual environments [7]. The study conducted by Bennet et al. exposed participants to a virtual environment (a 3D rendered office) with objects

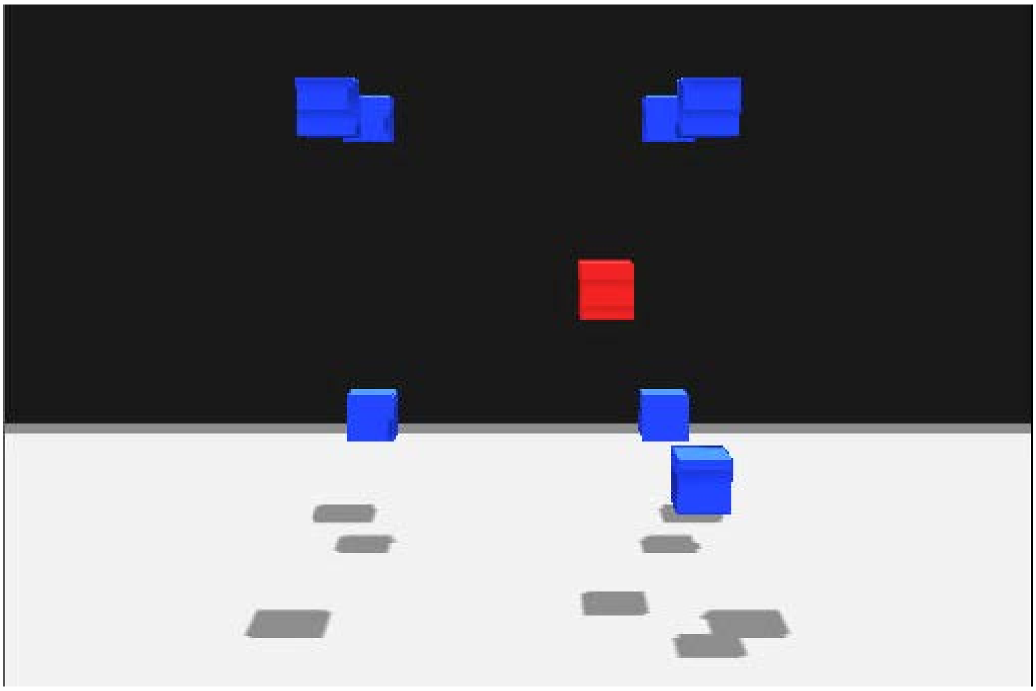

Figure 2.11: An example of a positioning task trial conducted by Hubona et al. in which participants had to re-position an object to complete a symmetrical geometric figure using either stereoscopic cues or shadow cues [48].

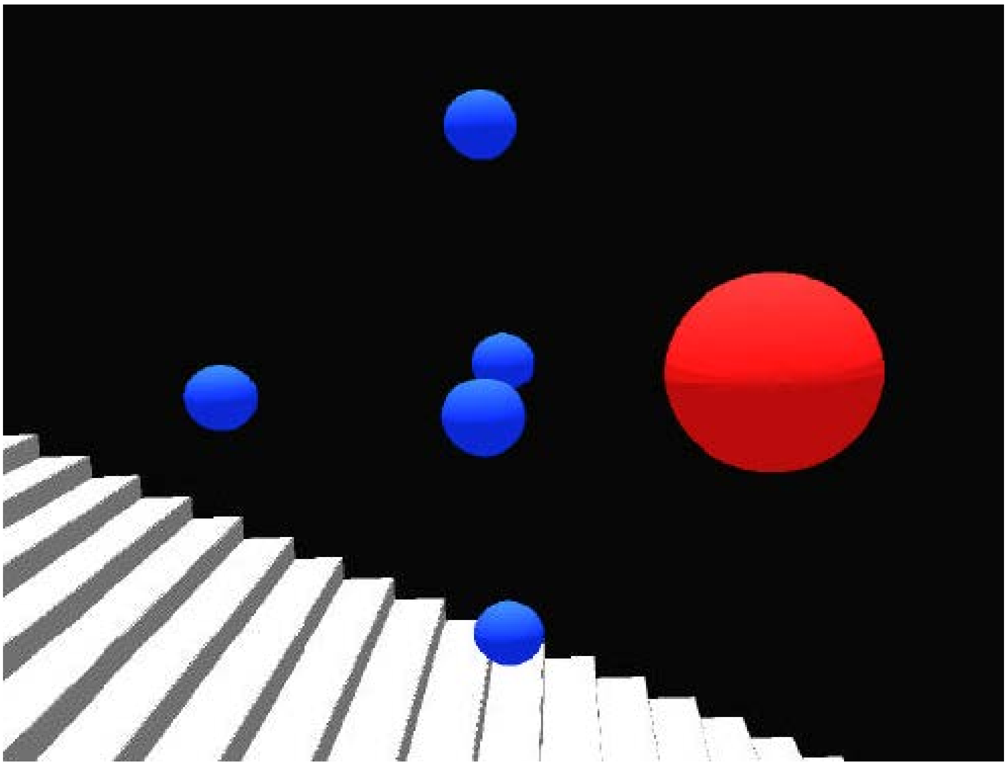

Figure 2.12: An example of a resizing task trial conducted by Hubona et al. in which participants had to resize an object to match the size of other objects using either stereoscopic cues or shadow cues [48].

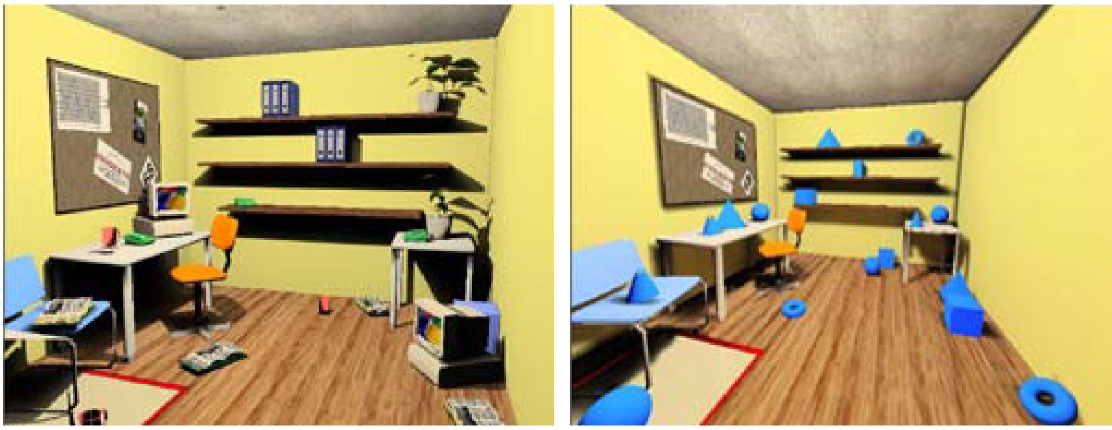

Figure 2.13: Experimental scene with office consistent objects (left) vs. primitive objects (right) in which stereoscopic viewing allowed for richer memory experiences in virtual environments [7].

consistent with an office setting or primitive objects located in similar positions (see Figure 2.13)[7]. After viewing the scene for 120 seconds the participants were then tested on their memory of the location of each object. This was both a spatial awareness task as well as a memory task. It was found that the two groups of subjects exposed to stereoscopic cues outperformed the two groups that did not view the scene with stereoscopic cues, with respect to the vividness of their memory experiences. However, a different study by Bastanlar et al. showed no significant difference between 3D and 2D groups both on feeling of presence and object recognition/navigation performance [4]. The participants of the study were asked to navigate a two-floor virtual museum, in either stereoscopic 3D viewing conditions or traditional 2D viewing conditions. Results showed no significant difference between 3D and 2D groups neither on feeling of presence nor object recognition/navigation performance, however Bastanlar et al. report that due to the simplicity or lack of realism in the environment, the participants may have never been engaged in the content, so it would be difficult for S3D to enhance that engagement [4].

User performance in S3D has also been extended to real-world applications. An example of this is teleoperation, where "results have shown that S3D can aid teleoperation by reducing task execution times, reducing error rates, and reducing the time needed for training" [34]. Another advantage of S3D teleoperation is the reduction of the training and practice time needed for skilled teleoperation [34]. There have been other works which discuss the advantage of S3D in cockpit situational awareness tasks as well, such as the use of S3D in a flight simulator [11], or a dynamic air simulation display [68]. The use of stereoscopic viewing mixed with three-dimensional echocardiography has decreased the time required for surgical task completion and increased the precision of instrument navigation, potentially improving the safety of beating-heart intracardiac surgical interventions [105].

However, not everything in the literature points to a consensus on the superiority of S3D. In a three-axis manual tracking task [56], though stereoscopic displays do generally permit superior tracking performance, monoscopic displays allowed equivalent performance (provided they were defined with optimal perspective parameters and adequate visual enhancements). Another study [39] hypothesized that stereopsis may allow for better performance when given a mental rotation task. However, depth information provided by disparity was not needed to perform the task at all, therefore stereopsis did not add any benefit to the participants. It is not uncommon in the literature to find experiments attempting to compare stereopsis with other cues while using tasks that may not require the use of the depth cue.

2.5.4 Stereoscopic 3D in Games

Some studies suggest that stereoscopic gaming may enhance the entertainment experience in game playing [80]. For this reason, stereoscopic rendering effects have been used in recreational games for many years. Early attempts at attracting gamers to stereoscopic 3D content can be dated back to the use of "VR-Games" that were played exclusively in arcades. Arcade games, such as SubRoc 3D (see Figure 2.14) and the Virtuality series [112], incorporated full head-mounted displays to provide stereoscopic 3D viewing and were very popular, but were far too expensive to be replicated for home use. Another failed attempt in the past to bring stereoscopic 3D content to the users home was the use of the Nintendo's Virtual Boy (see Figure 2.15).

The Nintendo Virtual Boy was first introduced in 1995 and was the first and only dedicated stereoscopic video game console released to the general public [119]. It worked by using oscillating mirrors displaying a linear array of lines, powered by LEDs (Light Emitting Diode), one for each eye (see Figure 2.16), providing a final 3D image in seen in red and black. Although many users attributed the failure to the shortcomings of the device itself, a recent review of Nintendo's Virtual Boy attributes the failure to the actual content, which lacked both a focused design, and gameplay mechanics which should have been designed specifically to take utilize stereoscopic 3D viewing. After reviewing the device, researchers concluded that there must be an active search for games that work better using stereoscopic 3D

Figure 2.14: SubRoc-3D is an arcade game released in 1982 by Sega, and the first such game to provide a three-dimensional image to the player. It employed a display that delivers individual images to each eye, achieved by using a viewer with spinning discs to alternate left and right images to the player's eye from a single monitor [115].

Figure 2.15: An early attempt at stereoscopic 3D gaming, Nintendo's VirtualBoy is regarded as a failure due to: i) its lack of defined identity as a product, ii) a comparatively weak display, iii) its socially isolating game experience, iv) purported negative effects, v) the challenges in explaining and demonstrating stereoscopic gaming, vi) and its lack of a must-have game [119].

viewing than traditional vision if stereoscopic 3D should continue to be in use [119].

In recent years stereoscopic 3D games have seen a resurgence thanks in part to the availability of improved and affordable (consumer level) hardware such as S3D equipped home televisions and mobile devices. However, despite the hardware improvements and the large scale availability of affordable stereoscopic 3D hardware, stereoscopic 3D content is still lacking and has unfortunately not kept pace [117]. Many of the games that currently support stereoscopic 3D still do not adequately make use of the additional information afforded by stereoscopic 3D. In other words, they are not designed specifically for stereoscopic 3D but are rather created natively in 2D and then converted for 3D use. These games are not built to take advantage of stereoscopic 3D in terms of game mechanics and user interface [61]. This is contrary to what most users desire. In a survey conducted in 2010, an overwhelming majority of users would like game developers to natively support stereoscopic 3D in their games [90].

The advantage of stereoscopic 3D gaming has been examined extensively. In terms of preference, the literature points to the consensus that users prefer playing games in stereoscopic 3D than traditional viewing [61]. In some cases, over 85% of users preferred stereoscopic 3D viewing rather than traditional viewing when playing a game [81]. Other studies have pointed towards an increase in emotional arousal [81], higher Game Engagement Questionnaire (GEQ) results (a survey to measure engagement levels during gameplay) [88] and overall higher presence and immersion than that of stereoscopic 3D viewing allows for. Generally, players feel more immersed within the stereoscopic game and are greater motivated to actively participate. These effects were evoked especially in males, allowing for a more natural and less self-reflective gameplay session [88].

Some studies however attempt to explain that these effects and the preferences for stereoscopic 3D content exist only for games which provide an overall advantage using S3D [59]. The same can be seen when looking at user performance benefits in stereoscopic 3D viewing compared to traditional viewing. Past research confirms that if games are designed with 3D spatial tasks in mind, stereoscopic 3D can improve user performance [61]. This improvement may also be limited to certain isolated tasks that require a higher level of spatial awareness than the rest of the game [59] [101] [38]. An example of this can be seen in the study performed by Laviola et al. in which multiple games were selected for testing between stereoscopic and traditional viewing techniques. In a game where the player interacted with only one object at a time with a more or less static background environment (e.g., aiming a cue ball or putting blocks on a table in 3D space), significant performance benefits occurred for stereoscopic 3D over a traditional 2D display. However, in more complex scenes, no performance benefits were observed [61]. This is contrary to some other studies conducted which state that participants are able to grasp larger and more complex scenes with more understanding by using S3D [108]. However, the gaming literature confirms that "relatively simple scenes or static environments where interaction is focused on isolated tasks" must be utilized to provide user performance benefits in stereoscopic 3D [61]. Many prior studies pointing to no user performance benefits due to the use of stereoscopic 3D have been dismissed due the nature of the games that they were using [81]. This finding was in line with LaViola et al. in which the games that were studied made little to no use of the depth axis, which disallowed a stereoscopic effect to make any difference to the user [61].

Additionally in the literature it was found that beginners made better use of stereoscopic 3D cues than expert gamers. Expert gamers were able to utilize other monoscopic depth cues which are always present (such as shadows), putting less of a reliance on any stereoscopic cues at all, making their performance on both viewing modes equivalent [61]. A similar result can be seen with respect to the prolonged use of a stereoscopic 3D game, where user performance benefits exist at first but diminish after prolonged game play [81]. This may be explained by the increase in skill participants witness when playing the same game over a long time, although they may have used the S3D cues at first during their "beginner" experience level, they quickly learn enough of the game to rely on other cues instead.

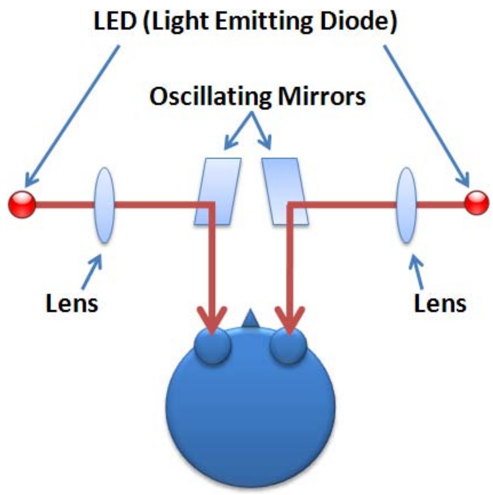

Figure 2.16: Virtual boy technical operating principle [119].

Issues with Comfort in Stereoscopic 3D Games

Stereoscopic 3D games have also been overlooked due to a popular idea that they may be uncomfortable for the user. In a game simulator, eye strain and disorientation symptoms were significantly elevated when looking at stereoscopic viewing compared to traditional viewing [44]. This is attributed to the convergence-accommodation conflict that is produced in the players oculomotor system when the game is being viewed [117]. Excessive parallax, on both the positive or negative side, can cause this discomfort, although it has been confirmed that negative parallax causes greater visual fatigue because the discrepancy between accommodation and convergence increase [117]. The pain or discomfort can be significantly reduced by using smaller depth values [43] [93] and is something often experimented with by game developers. Some developers suggest exact parallax levels to create optimal playing environments for the user [87]. However, there is no literature to confirm where these values come from, or whether they are optimal for a user, since many factors attribute to the stereoscopic vision of a player, even their age [31].

Learning effects in Stereoscopic 3D in Games

Although it is not confirmed, and very little literature exists when addressing learning rates, it has been proposed by previous literature that learning rates can be increased by stereoscopic 3D viewing [61]. LaViola et al. examined three separate entertainment games and found that participants viewing in stereoscopic 3D had learned more than participants viewing in traditional viewing [61]. If the utilization of stereoscopic 3D improves learning rates than this could be very beneficial for the serious, educational and training game market. It is the purpose of this thesis to expand on the scarce literature that exists by investigating learning rates within a serious game that employs a stereoscopic 3D viewing environment.

Chapter 3

Fire Safety Training Game

The fire safety training game was created to aid and educate chemical lab instructors in an institutional environment. Although the game can be beneficial to anyone exposed to hazardous chemical fire situations, it was created specifically with an instructor within a typical university laboratory in mind since they are the designated fire marshals in case of fire and they are held most responsible to uphold a safe protocols in case of emergency. Choosing to centre the scenarios around a chemical lab instructor allowed for easy access to university chemical labs, and equipment, which provided reference material to replicate physical environment and create from it a virtual environment. Also, access to personnel was an added benefit, since their involvement would allow for expert feedback during development. Additionally, those personnel could also serve as potential subjects for future effectiveness testing.

The game was intended to be a memory aid, augmenting traditional training approaches and not replacing them. The game can be played periodically to refresh lab instructors on procedures and common mistakes made during chemical lab fires, as well as general guidelines to prevent chemical fires. It also teaches the proper method to extinguish a fire, commonly referred to as the P.A.S.S method, in which the user must perform four steps in order to extinguish a fire: i) Pull the pin to (located near the handle of the extinguisher) to break the tamper seal, ii) Aim the extinguisher nozzle at the base of the fire, iii) Squeeze the handle to release the extinguishing agent and iv) Sweep from side to side at the base of the fire until it appears to be out [86] (Figure 3.1).

A full overview of the game has been published [70].

Figure 3.1: The P.A.S.S technique employed to safely extinguish a fire is an important aspect of fire safety. Image taken from United States Department of Labor [86].

3.1 The Scenario Mode

Users begin the serious game in a laboratory taking on the role of either a laboratory user, instructor, or manager viewing the scene in a first-person perspective (Figure 3.2). Several other non-player characters (NPCs) also appear in the scene (other lab users, etc.). The user/trainee has the ability to move throughout the environment (lab) using typical first-person controls and more specifically, the "W", "A", "S", and "D" keys to "forward", "left", "right", and "backward" and the mouse to rotate the "camera". The game has been customized to allow for game controller input, which assigns the left directional stick to the players movement, while the right directional stick represents the camera's movement, or in this case replaces the mouse. Within the virtual world, users encounter a particular fire emergency incidence that requires their response. The user then carries out their required tasks which involves making various choices (e.g., if the fire can be contained, they must evacuate students from the room, obtain the fire extinguisher, safely put out the fire using proper technique, and call the main office to report the incident). Making the correct choice increases their "score" and allows them to proceed with the scenario whereas an incorrect choice decreases their "score" and presents them with information indicating why their choice was incorrect.

Although trainees are able to read about incidence response (e.g., chemical lab fire safety) in various textbooks and Health and Safety guidelines, we take a situated learning approach in which the learning environment is modelled on the context whereby the knowledge is expected to be applied [26]. In other words, given that the trainees are expected to respond to an incidence within their own workplace, the serious game will place the student/trainee within this same context. Fur-

Figure 3.2: "Sample screenshot illustrating a portion of the chemical laboratory in which the scenario is based. The chemical laboratory was modelled after a faculty of science chemical laboratory at the University of Ontario Institute of Technology in Oshawa, Ontario, Canada"

thermore, 3D technologies (3D graphics, 3D sound rendering, and stereoscopic 3D graphics) are employed to provide sensory realism consistent with the real-world, ensuring that the knowledge gained within the serious game can be more easily recalled and applied when the trainee is placed in the real world scenario [26].

3.1.1 The HUD

Although cross-hairs and cursors may help with precision in terms of viewing direction, especially in first-person-view games, there were no requirements for such precision in the game so it was decided to remove the cursor altogether and have nothing obstructing the players view. Furthermore, the cross-hair can also act as an extra piece of information that may make the game feel too similar to recreational games and encourage users to treat the game as a mere arcade game, acting in ways they would not in real life and reducing the learning effect as a product of their actions [94]. A strong intention was made throughout the development of the game to remove as many ineffective "game-like" pieces of information from the screen so that the users immersion would not be broken, and the game would be kept as close to real life as possible. However, not all extra or assistant visual information cues were removed. There were many interactive objects placed around the environment which could be selected as long as the user was looking at it. It would be extremely difficult to determine which object a user is looking at, since in real life we focus on objects so quickly it goes unnoticed, yet in a game it would be impossible to determine what object a user was looking at on the monitor itself. It was decided to have the in-game player to "focus" on an object depending on their distance to

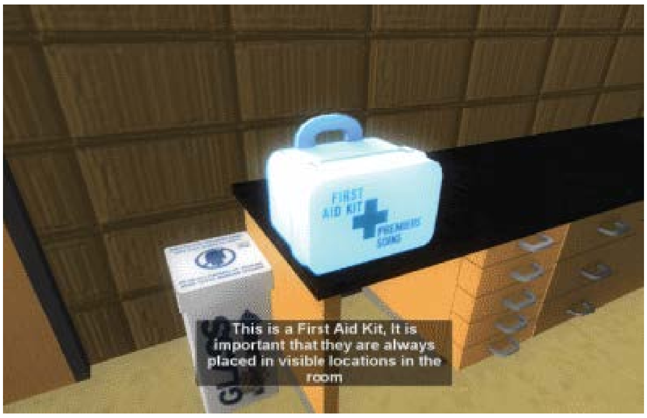

Figure 3.3: An interactive object that is within the players view will glow blue, and when the player is close to the object, text is displayed providing the player with information regarding the object.

the centre of the camera's focal point. If an object is within a certain distance from that focal point, it will appear to glow, encouraging the user to focus on that object (Figure 3.3). Highlighting objects in this manner has been shown to reduce cognitive load [104] and by restricting the "selectable" objects within the players field of view, we approximate the real-life phenomenon of "tunnel vision" that occurs during a real emergency [107].

3.1.2 The Scenarios

The serious game itself consists of the underlying framework (primarily the graphics and sound rendering engines) and scenarios. Scenarios are developed on top of the framework and cover specific situations such as a chemical fire or chemical spill. The player's/user's task in each scenario is to respond to the particular "emergency" outlined in the scenario following the appropriate emergency response guidelines. Players are rewarded for following appropriate emergency measures and penalized otherwise; the aim is to respond to the emergency outlined in a scenario while maximizing their score. Intentions were placed on providing feedback to the user only after the entire scenario is completed. It's often stated that learning from mistakes may be more beneficial than if they weren't made at all. In a serious game, it is both cost-effective and safe to commit the mistakes that if happened in real life may result to both damages as well as death. Feedback is also be provided at the end of the scenario even to those who run the scenario flawlessly since a confirmation would be needed to explain why the actions the user had performed were correct to both reinforce their decision and allow for reflection. Currently, the game supports four different scenarios. The major variants between the scenarios are: the location of the fire (is it occurring inside or outside the room), the size of the fire (is it too large to safely extinguish), and whether any hazardous materials are located near the fire. The interactive actions that the user may need to perform in a correct order specific to the scenario are: calling security, evacuating the room of personnel, picking up an extinguisher, extinguishing the fire and leaving the room locked. Each scenario differs with respect to the actions that need to be performed, allowing users to make mistakes and be provided with feedback after the entire scenario had been complete.

3.1.3 "Teaching Proper P.A.S.S Method" Micro-game

The serious game employs the concept of "micro-games" [6] or "games within a game" which involve the use of smaller "sub-games" within the game itself. A micro-game is used to introduce the players to the cognitive process underlying the proper use of fire extinguishers, which is an essential part of fire-safety training, since using an extinguisher in real life would lead to large clean-up costs, and retardant replacement fees, as well as risking damage to the extinguisher. When the player attempts to extinguish a fire by picking up the extinguisher and "using it" near a fire (this is done simply by pressing the action button), a micro-game is started which encourages the user to learn and demonstrate proper use of the P.A.S.S. method. At the start of the micro-game, the game breaks away from the first-person view as well as controls, signifying a change in both pace and environment in hopes that the user will pay special attention to the micro-game. The user is spawned in a "virtual room", textured with a checker-board material layer on walls and ceilings, with a view of a the fire in front of the user and the extinguisher still in the players hands. The player then runs through each individual step in the P.A.S.S method concluding with the successful extinguishing of the fire. The steps are all completed by mouse clicks and drags of some kind (Figure 3.4). The user first must click and drag the pin out from the extinguisher. Then they must aim at the base of the fire, being assisted by a visual 'aura of influence' in which the retardant will hit. Finally, the user must click and drag the handle to squeeze, and sweep across the base of the fire to extinguish it. Upon completion, the player successfully extinguishes the fire and the micro-game is exited, bringing the user back to the scenario where they had left off.

3.1.4 Environmental and Physiological Effects

In previous studies, it has been concluded that participants have a weak knowledge of both environmental and physiological effects on the user's avatar (i.e., digital

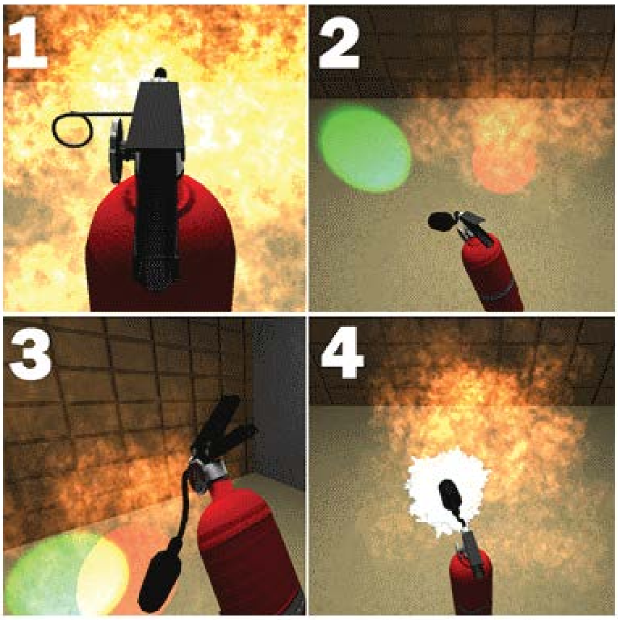

Figure 3.4: A micro-game teaching the P.A.S.S method. 1) Prompts user to pull pin. 2) Prompts user to aim. 3) Prompts user to squeeze handle. 4) Prompts user to maneuver sweeping motion.

representation of the user [14]). A user requires feedback to know if they are staying close to a fire for a long period of time, and breathing in toxic fumes, or if they are too close to a fire and feeling pain from the heat of the fire. Of course, many of these effects cannot be represented directly as they would in real life, however they can be substituted with audio or visual cues that bear some resemblance. We employ the use of various shaders to induce panic and urgency in the player, as their avatar experiences the effects of smoke inhalation, and overall stress due to prolonged experience in a critical incident (fire in particular for this scenario). Depending on the proximity to the fire, and how large the fire is, the players "health" will begin to decrease, and with that, additional visual effects are added to convey to the player that they are currently in immediate danger and that they are being harmed. To accomplish this, a vignette shader around the edges of the screen and a blur closing in on those edges to approximate the real-life phenomenon of "tunnel vision" that occurs during a real emergency [6] is employed. Motion blur near the late stages of exposure is also included. This type of feedback was used to simulate loss of consciousness as a result of toxic fumes, which has been requested by players of other games which attempted to tackle the same problems [14].

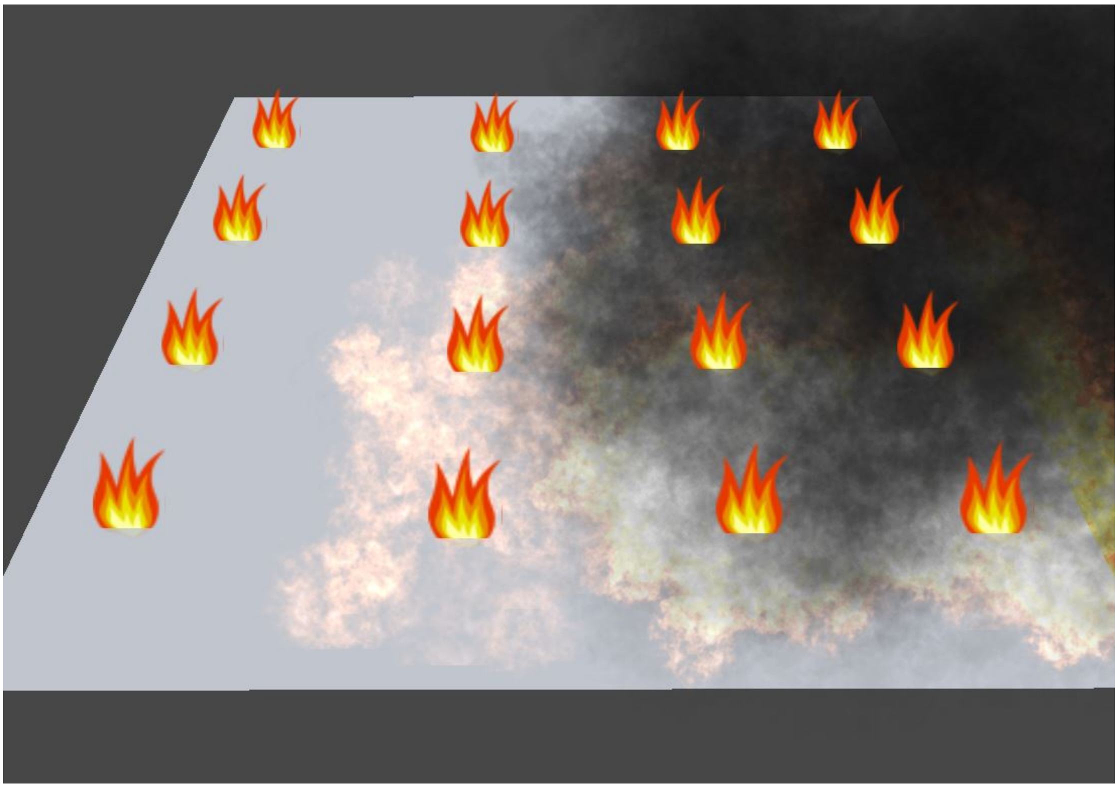

Figure 3.5: Fire nodes were placed around the room to simulate a real fire-spreading environment.

The Fire

The fire also spreads throughout the room similar to that of a real fire. While creating the layout of the room, flammable nodes were placed around the lab. Every node was attached, so that dormant nodes (nodes that are currently not ignited) continually check if neighbour nodes within a radius are already ignited. If they are, than the dormant node's heat tolerance value (a value set by the developers) continually decrease depending on how many lit fires are within its radius, and what distance the fire is relative to themselves. After the heat tolerance of the dormant node drops below zero, the dormant node ignites and becomes an active fire node. This allowed for the simulation of a fire spreading in a room similar to how it would in real life (Figure 3.5).

3.1.5 Technical Details

The serious game was developed using the Unity3D™ game engine. Unity3D™ is a commercial game engine which provides a developer with a variety of useful tools and scripts, as well as the underlying engine which will take care of things like windowing, sound, graphics, input, and physics that increases the speed at which one can create a game. Although an engine such as Unity is usually used for commercial games, there has been a recent surge of serious games developed with commercial game engines [94]. Given its integrated development environment with re-usable game components, the use of Unity3D™ reduces the amount of work needed to produce the game, allowing developers to focus on the higher level aspects of the game itself (i.e., development of the scenario) rather than focusing on the technical details associated with rendering of graphics, visuals and sounds for example. The entire room (lab) and all of its components were modelled and textured "from scratch" (pre-existing models were not used). The lab itself is modelled after an actual Faculty of Science chemical laboratory at the University of Ontario Institute of Technology (Oshawa, Ontario, Canada). The 3D modellers/artists were granted access to a chemical lab and took various pictures of objects and textures, and were able to replicate them digitally, and placed incorporate them into the scene. The fire is displayed as a particle effect which is available within the Unity3D™ game engine.

Using the FOV2GO plugin, stereoscopic 3D viewing techniques were utilized, allowing the player to play the game in stereoscopic 3D. This required an active stereo monitor, and active stereo glasses. The zero parallax barrier was placed 0.3 units into the screen, which was nearly the same depth as the extinguisher. This was done to avoid having the extinguisher create too much negative parallax in the scene due to the close distance the extinguisher had to be from the camera at all times.

Chapter 4

Engagement in Stereoscopic 3D

4.1 Measuring Engagement in Stereoscopic 3D

A study was conducted to measure player engagement in a stereoscopic 3D video game [46]. The purpose of this study was to determine whether a user is more engaged in a game environment, while viewing in traditional 2D or in stereoscopic 3D. Participants played a video game in two conditions, traditional 2D and stereoscopic 3D and their engagement was quantified using a previously validated self-reporting tool. The results of this study bring us closer to understanding how stereoscopic 3D content can affect player engagement, and this can be of importance when developing effective serious games such as the fire safety training game described in Chapter 3.

4.1.1 Participants

The participants were comprised of 20 volunteer students from the University of Ontario, Institute of Technology (UOIT). These students were all enrolled in the Game Development and Entrepreneurship program at UOIT. The age of the participants ranged from 18-26, with the majority of participants being 18-20, and were all male, aside from one female. Due to the gender unbalance, the results were run only with the male participants, leaving size of N=19. Results from the demographic questionnaire given to the participants prior to the study indicate that seven of the nineteen students had never played a stereoscopic 3D game in the past, and one participant had never watched a stereoscopic 3D movie before. The experiment abided by the University of Ontario Institute of Technology Research

Figure 4.1: Screenshot of Trine. Copyright Frozenbyte studios.

Ethics Board Ethics Review process (R.E.B #11-004) for experiments involving human participants.

4.1.2 Experimental Method

The study was conducted in the undergraduate game development laboratory at UOIT. The dimensions of the laboratory were 40.0 m × 20.0 m × 9.5 m and the room was cleared of any others so that only the participants and the experimenters were in the room. Participants were seated in front of a 24" Zalman Trimon (ZM-M240W) passively polarized stereoscopic display. The game Trine by Frozenbyte studios (Figure 4.1) was chosen due to the superb quality of the stereoscopic experience, as recommended by an online stereoscopic gaming community, "Meant to be Seen" (MTBS3D), "The world's first and only stereoscopic 3D Certification and Advocacy group" [90].

Although the game was developed to be viewed on traditional 2D enabled monitors, many software manufacturers create software solutions to convert 2D content to stereoscopic 3D content for viewing on stereoscopic 3D enabled monitors. Amongst these software packages is TriDef 3D, created by DDD, which converts videos, games and photos from 2D to 3D for PCs [28]. The TriDef stereoscopic driver from DDD was chosen out of many other software packages for its ability to control the depth and percentage out of screen with a higher degree of control than all the other options available. There was also the added benefit of being able to use settings already defined and recommended by members of MTBS3D for the stereoscopic driver.

Trine is a side-scrolling puzzle-platformer whereby the player must move to the left, right and solve puzzles by using a variety of character abilities such as grappling hooks, or magic. Trine is simple to understand allowing participants with little to no experience with side-scrolling puzzle-platformers to play for an extended period of time without any issues. The game also begins with a tutorial level, teaching the basic concepts of the game for any new participants.

As previously mentioned, each participant was seated, they were asked to complete a demographic questionnaire prior to the test to determine their gaming habits and past experience with stereoscopic 3D games. Following the completion of the questionnaire, each participant was required to play the game under two visual conditions, i) traditional 2D, and ii) stereoscopic 3D. To ensure that the participants were not aware of which condition was being presented first, the traditional 2D version of the game was rendered using the stereoscopic drivers, however the stereoscopic images had no depth. Participants were required to wear 3D glasses for both conditions so that consistency was kept between both tests. Furthermore, using this approach ensured that any hardware performance issues resulting from rendering the images twice was consistent between both conditions.

Prior to the experiment, participants were randomly assigned to either Group A, which played the game in S3D first followed by 2D, or Group B, which played the game in the opposite ordering. The groups were counter-balanced to ensure a fair analysis. The participants played the game for 35 minutes in either the traditional 2D or stereoscopic 3D condition, as defined by the whichever group they belonged too. Immediately after playing the game, the participants were asked to complete the Game Engagement Questionnaire (GEQ), which is described in greater detail below. Participants were given a break for five minutes and then completed the second experimental condition according to whichever group they belonged to. Once both conditions were completed and the corresponding GEQs were completed (one GEQ for each condition), the participants were asked for their general free-form comments.

The Game Engagement Questionnaire

The GEQ provides a psychometrically strong measure of levels of engagement specifically elicited while playing video games, and was used as the assessment

	Questions	Engagement Measure
1	I lose track of time	Presence
2	Things seem to happen automatically	Presence
3	I feel different	Absorption
4	I feel scared	Absorption
5	The game feels real	Flow
6	If someone talks to me, I don't hear them	Flow
7	I get wound up	Flow
8	Time seems to kind of stand still or stop	Absorption
9	I feel spaced out	Absorption
10	I don't answer when someone talks to me	Flow
11	I can't tell that I'm getting tired	Flow
12	Playing seems automatic	Flow
13	My thoughts go fast	Presence
14	I lose track of where I am	Absorption
15	I play without thinking about how to play	Flow
16	Playing makes me feel calm	Flow
17	I play longer than I meant to	Presence
18	I really get into the game	Immersion
19	I feel like I just can't stop playing	Flow

Figure 4.2: Game Engagement Questionnaire [12]. Responses are No=1, Maybe=2, Yes=3.

tool since it had published statistical results that indicate it as being a good measure of engagement [12]. It consists of 19 questions (see Figure 4.2) that seek to provide and indication of immersion, flow, presence or absorption in the content. The participant is able to respond to each question with either Yes, No or Maybe, and a numerical value is assigned to each response: Yes=3, No=1, Maybe=2. The total sum of the responses (GEQ total score) is proportional to player engagement, where higher scores indicate higher engagement in the game's content.

4.2 Results

4.2.1 Participant Demographics

In the demographic questionnaire, participants were asked to rate their experiences with traditional 2D and stereoscopic 3D. Given a seven point scale (1=2D is much more enjoyable, 7=stereoscopic 3D is much more enjoyable), participants gave an average (mean) rating of 4.38 (SD=0.76) for video games and 4.57 (SD=1.60) for movies. Essentially, participants were neutral towards S3D. Participants were also asked to rate, on a five point scale (1=not important, 5=most important), qualities of video games. In order of most importance to least importance, average ratings were reported as follows; i) Single-player gameplay (4.45), ii) quality of interaction (4.25), iii) story (4.1), iv) audio quality (4), v) multi-player gameplay (3.7), vi) realistic graphics (3.45), vii) surround sound audio (3.3).

Also, for stereoscopic 3D video games, participants were asked to rate the importance of stereoscopic qualities, and reported the following average ratings, in order of most importance to least importance: i) playing for more than 1 hours (3.85), ii) out of screen effects (3.8), iii) seeing deeply into the screen (3.75), iv) not wearing glasses during gameplay (3.45). The results to additional questions are available in Appendix A.1

4.2.2 Free-Form Comments

In the free-form comments section of the survey, 80% of the participants described the stereoscopic experience as compelling, fun, engaging, and interesting. 40% of the participants reported that the stereoscopic 3D condition was uncomfortable due to the difficulty of focusing on the transient out of screen effects and images, as well as seeing two of the same image, (a phenomena known as crosstalk, in which each eyes opposing image is not completely blocked out by the polarized filter, creating what appears to be a 'doubled up' image). Notable responses were:

> "I thought the 3D was more fun but I was so immersed I missed some important pop ups such as when the characters leveled up" (Participant 21, November 2011).

> "3D was definitely better. The feel of depth made a huge difference. If I had a 3D TV I would invest in 3D games" (Participant 19, November 2011).

> "Both sessions were fun, however it was much harder for me to play the 3D one of the two because my eyes were not able to focus clearly. As a result many of the things that were supposed to be appearing to pop out of the screen ended up appearing as two images. This also caused me to get a headache. While playing the 2D version, I felt more immersed into the experienced but that may be simply because I wasn't so focused on trying to see the game properly". (Participant 1, November 2011).

4.2.3 Game Engagement Scores

Participants' total scores from the Game Engagement Questionnaire during the stereoscopic 3D game and non-stereoscopic 2D game condition were compared using a paired-samples t-test. The analysis indicated that there was no significant difference between the total scores in the 3D game condition (M = 35.15, SD = 8.25) and the 2D game condition (M = 32.85, SD = 7.15), t (19) = 1.78, p = .091. These results suggest that participants do not experience a greater sense of engagement when playing the video game in stereoscopic 3D than in 2D.

4.3 Discussion

4.3.1 User Engagement in Trine

After conducting the study that examined user engagement in Frozenbytes' Trine, it was found that there was no significant difference in terms of player engagement whether the game was played in stereoscopic 3D or in traditional 2D. This at first seems contrary to results seen by Rajae et al. [81], and Schild et al. [88] in stating that stereoscopic 3D allows for greater engagement in games, however when looking closely at their results, they state that a significant difference was seen only in games that make use of the depth axis in its game mechanics. Trine makes little to no use of the depth axis since it is a 2D game played only along the x and y axes. Therefore, the lack of significant difference between the two viewing modes observed in this study in fact confirm Rajae et al. [81], and Schild et al. [88], stating that S3D does not engage the user any more than traditional 2D, in a game that makes no use of the depth axis. The results of this study suggest to game developers that S3D is ineffective in terms of player engagement in a game that makes no use of the depth axis, specifically a 2D game.

4.3.2 Game Selection

Schild et al. suggest that higher engagement was found in games involving depth animations. Since Trine takes place entirely on a 2D plane, there are no depth animations, which leads us to hypothesize that had this study been performed with a more depth-involved game, such as a first-person shooter, engagement scores from the GEQ would have been higher when playing the game in stereoscopic 3D.

4.3.3 Novelty Effect

Since seven of the nineteen participants had not experienced a game in stereoscopic 3D before, than there could have been a novelty effect in play, which users who have never played in stereoscopic 3D before been more engaged in the content due to the mere novelty of the stereoscopic effect. While the novelty effect may have had some effect on users' attention causing them to pay more attention to the game when viewed in stereoscopic 3D, there is no literature to support that engagement as evaluated by the GEQ is affected by novelty.

4.3.4 Free-form Comments

The free-form comments indicate that there is a need for individualized calibration. In the study participants were not permitted to change their own S3D settings in order to ensure consistency amongst trials. However, this may have created an uncomfortable experience for some participants, since S3D is perceived differently amongst participants [88]. In addition to ensuring consistency across all participants, it was also believed that the S3D calibration menu used in the experiment (provided by DDD drivers) would be too complicated for an average consumer to understand. Therefore, even if participants were allowed to calibrate their stereoscopic 3D display, more seamless calibration configuration would have to be utilized, although even then there would be no guarantee that users would end up with the most satisfactory settings.

Chapter 5

Calibration of Stereoscopic 3D settings

5.1 User Study on Preference of Stereoscopic 3D Settings

Since stereoscopic 3D effects in games can vary depending on the viewer [88], customizability is seen as a core advantage to at-home stereoscopic entertainment. If a serious game was to be rendered in S3D, it would be important to choose the ideal settings so that users are not uncomfortable and the image is seen with an appropriate amount of stereoscopic depth. The goals of this study were twofold: i) investigate interactive approaches to setting these parameters (i.e., an interactive S3D calibration system), and ii) to compare the final stereoscopic settings with the methods provided by the content developers. In this experiment, two stereoscopic 3D calibration methods were used to set the interaxial distance between the stereoscopic pair of images. The first method (the slider method) is similar to the methods used in typical games, while the second method (S3D lens method) was developed to reduce the effort required by the user during the calibration stage. The results of this study brings us closer to developing a greater understanding of stereoscopic 3D calibration techniques and which technique may work best for a fire safety training game as well as other serious games.

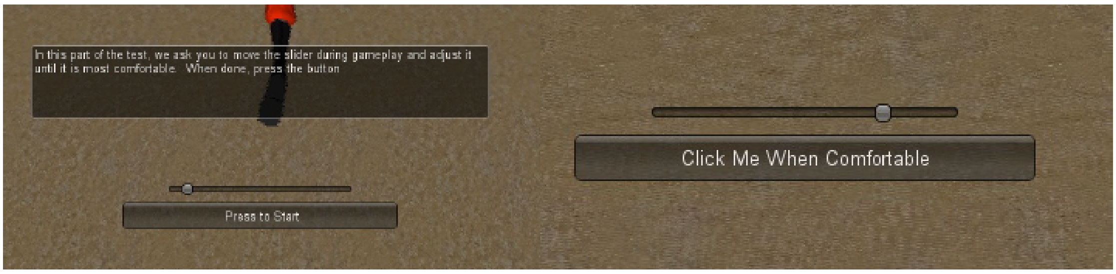

Figure 5.1: Slider method. Close-up of the in-game slider and the instructions presented to the participants. The slider allows the user to modify the interaxial distance between the stereosocpic 3D cameras while viewing the game environment.

5.1.1 The Game

The game employed for this study was a simple third-person view "run and jump game", and was developed in-house using the Unity 3D game engine. The Stereoskopix 3D plugin (now called FOV2GO) was employed to provide stereoscopic rendering support. The player was spawned on top of a building at the start of the game, and had to successfully jump from building to building by pressing the space-bar key in order to complete the game. If the player jumped at the incorrect time, they fell between the buildings and were re-spawned at the building from which they fell from. The user would be prompted to change their S3D settings throughout the gameplay session according to which method was currently assigned to them.

5.1.2 The Calibration Methods

Two methods were studied that users would use to calibrate their stereoscopic 3D game.

The Slider Method

The first method used to adjust the interaxial distance was a simple slider as shown in Figures 5.1 and 5.2. This slider is typical of methods currently used in commercial video game menus (and stereoscopic 3D drivers) to allow the user to adjust the amount of "depth" they can experience in the scene. Here, the slider simply controls one stereoscopic parameter (interaxial distance).

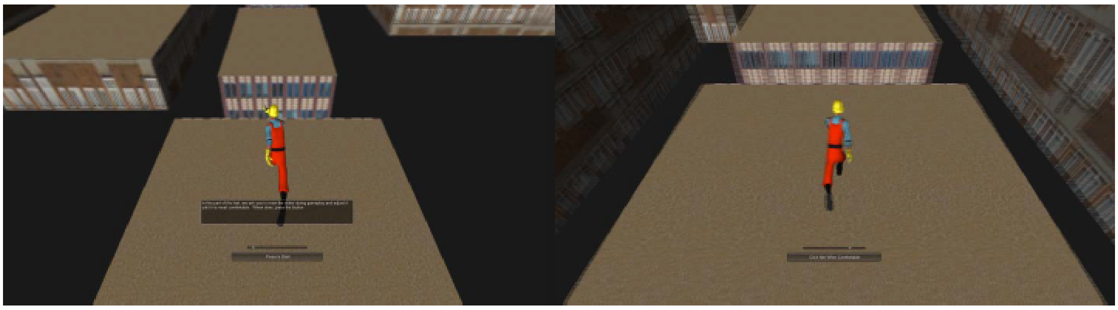

Figure 5.2: Slider method. View of the slider comparison trials.

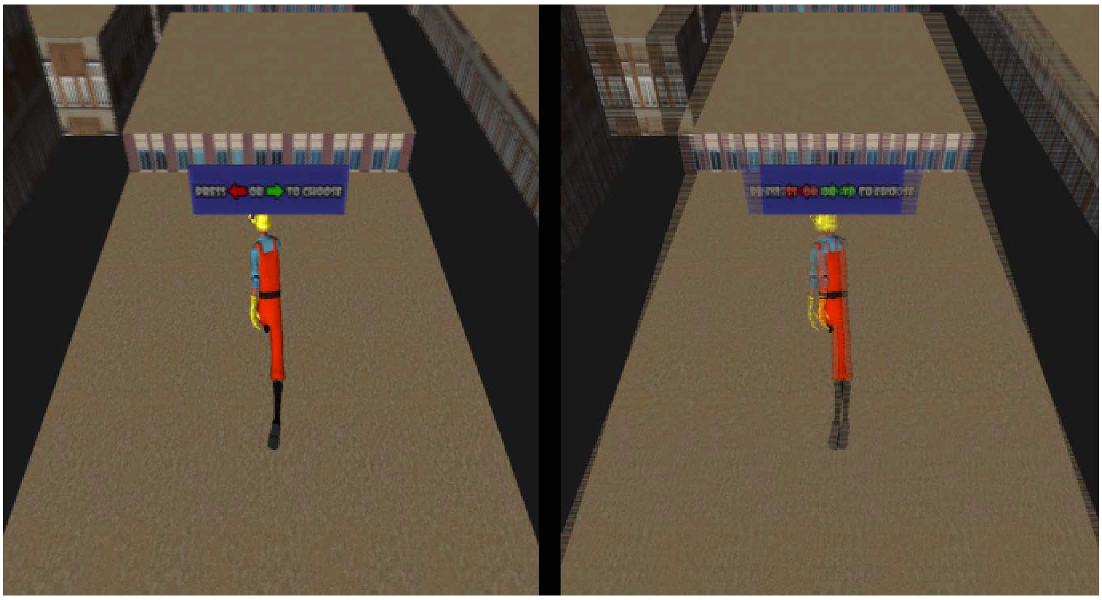

Figure 5.3: S3D lens method. The left and right halves of the display present the same scene but have different interaxial camera distances. Using the left or right arrow keys on the keyboard, users are able to select which parameters they prefer.

The S3D Lens Method

The second method for modifying the stereoscopic settings is an in-game comparison of two different stereoscopic 3D "lenses" as shown in Figure 5.3.

This method was inspired by standard testing methodologies utilized by optometrists, in which a "Lensmeter" is used to test for a patients refractive error [35]. This is done by the optometrist asking the patient to look through the "Lensmeter" and asking the patient if the eye chart (a chart around 20 feet away from the patient displaying different letters and symbols) appears more or less clear when different lenses are in place.

The game is presented in a split-screen with the same gameplay running consecutively in two screens, each screen with a different interaxial distance setting.

During gameplay, the user is asked to select the most satisfactory screen every five seconds. By using a process similar to optometrist tests, the user's optimal interaxial distance is selected. The algorithm used to converge on the preferred interaxial distance is provided (see Algorithm 1). The interval for the parameter was divided into 10 equal steps for setting the interaxial distances and upon each selection (selections were made using the left-right arrow keys), the left-right screens may have been swapped (50% chance of them being swapped).

Algorithm 1 S3D Lens Algorithm

```
Require: Screen 1 (left) always starts on the lowest setting
Require: Screen 2 (right) always starts on the lowest setting
  {Player selects their preference (left or right arrow keys)}
  while Selected setting != unselected setting do
    if (selected setting) > (unselected setting) then
      Update (unselected setting) to 1 step higher
    else
      if (selected setting) < (unselected setting) then
        Update (unselected setting) to 1 step lower
      end if
    end if
  end while
```

5.1.3 Participants

The participants were comprised of 22 volunteer students from the University of Ontario, Institute of Technology (UOIT). 77.3% of these students were enrolled in the Game Development and Entrepreneurship program at UOIT. The age of the participants ranged from 18-26, with the majority of participants ranging from 18-20, and only two of the participants being female. Due to the gender unbalance, the female participants were removed leaving a final size of N=20. Results from the demographic questionnaire given to the participants prior to the study indicate that 63.6% of participants had prior experience with S3D games. The experiment abided by the University of Ontario Institute of Technology Research Ethics Board Ethics Review process (R.E.B #11-004) for experiments involving human participants. All participants were initially screened using the standard Randot Stereo Test (as described in Section 6.1.3) to determine normal stereoscopic depth perception.

5.1.4 Experimental Method

Participants began by being seated in front of a desktop computer with a 24" Zalman Trimon (ZM-M240W) passively polarized stereoscopic display. After being de-briefed about the experiment, participants were asked to complete a demographic questionnaire to determine their gaming experience. Participants were then provided with an explanation of the controls and were told that they would be required to wear polarized glasses throughout the test as well as a motion tracking hat for research purposes. The participant's head position and orientation relative to the monitor was tracked using an Opitrack motion capture system to ensure that the users did not move beyond the "sweet-spot" of the monitors. To achieve proper stereoscopic 3D viewing with these particular monitors, the line from the user to the monitor was maintained at 90 degrees on the horizontal, and 12 degrees on the vertical. The game was then started at a paused screen, but with the player and buildings appearing in stereoscopic 3D and participants were asked to adjust their chair/monitor until they were in the stereoscopic "sweet-spot" of the display (by adjusting their position until they saw only one image as opposed to two seperate stereoscopic images). The game was synchronized with the motion capture system to initiate head tracking and the participant began the trials, first playing the S3D lens method followed by playing the game again using the slider method.

In both methods, participants were prompted with on-screen instructions to help select the most interaxial distance. Each trial ended when the player had made their choice (either automatically by the algorithm use in the lens method, or manually by the player in the slider method). The trial with both conditions was completed a second time, resulting in two sets of data for each condition for every participant for repeatability purposes. The participant was then asked to complete the free-form comments section of the survey.

5.2 Results

5.2.1 Free-Form Comments

In the free-form comments section of the survey, seven of the 22 participants (32%) complained that the stereoscopic 3D version of the game was too uncomfortable and hard to view. One of the participants went as far as to say,

> “The stereoscopic view gave me headaches after 5 minutes of playing.”. (Participant 3, September 19).

Another participant stated,

> “It’s really hard to find the right angle to view the game and sometimes it feels like I have to cross my eyes and it hurts a little.”. (Participant 9, September 19).

Two of the 22 (9%) participants also noticed red horizontal lines, which were due to a faulty video driver on the computer that they were tested on. However, given that they were only slightly noticeable, it is assumed that they had no effect on the results.. Three participants also voiced their concern about a faulty first trial due to their inability to fuse the two (left and right) images.

> “During the first set of tests, I think I was outside of the 3D sweet spot for the monitor”. (Participant 12, August 15).

Finally, some users also reported that the experiment may have been too boring, and would have appreciated a more engaging form of gameplay. This is captured in the following participant comment examples:

> ”All in all, the experiment may benefit from a more polished game.”. (Participant 10, August 15).

> “I did not enjoy how the experiment was very repetitive and that if there was more to the experiment such as better scenery it would be better.”. (Participant 4, September 19).

All of the participant free-form comments are available in Appendix A.2.1

5.2.2 Selected Interaxial Distance

Participants’ selected average interaxial distances from their S3D lens method gameplay and slider method gameplay were compared using a paired-samples t-test. There was no significant difference between the S3D lens average and the slider control averages ($p > 0.05$), $t(21) = -0.417$, $p = 0.681$. These results suggest that participants who used the S3D lens method chose similar S3D settings with the common slider method. Specifically, the S3D lens method is a feasible alternative to the slider method when choosing a calibration method. Also, running the data with and without female participants (who were removed from the analysis) did not produce any difference in results. Removing the two female participants was necessary since genders perceive S3D differently [88]. Head tracking also did not aid in the data analysis as participants stayed within the sweet spot range without any large/significant deviations worth noting.

5.3 Discussion

5.3.1 Interactive S3D Settings

The main contribution of this experiment was the development of a new and unique method for adjusting stereoscopic 3D parameters in a stereoscopic 3D game. This method was then compared to the common slider-based approach utilized by many commercial games. No significant difference was observed in the resulting interaxial distances that the users converged upon. These results indicate that the S3D slider method presented in this study is a viable method that can be employed by game developers. This provides another choice for designers who wish to develop user-adjustable stereoscopic parameters within their stereoscopic 3D content. This could be used in specific instances as an alternative to a slider method and allows for a full black-box approach where users will be adjusting their settings without feeling that they are, since this S3D setting calibration can be completely implemented as part of the gameplay.

5.3.2 The Game

There were inherent issues with using a simple "run and jump" game for this study. Although it was initially decided to use a very simple gaming mechanic, many participants became bored and uninterested since the mechanic was too simple. There was also no rewards (such as a score-based system) or penalties (such as a negative score impact for every fall, or even a loss condition), two primary engagement factors used in games. Adding components to the game that would make the S3D "lens" selection more central to the game-play may have resulted in more engaged players as well. For example, the game could have been populated with power-ups to generate a higher score and some of those power-ups selected the left screen, and some selected the right. This could have allowed for a more seamless S3D calibration process. However it would be vital to place the power-ups in such a way whereby players don't miss it or select the wrong power-up, because in this case they would not be penalized by a lower score (as a player normally would when missing a power-up), but by an uncomfortable gaming experience, which would only frustrate players. To summarize, the game may have lacked the seamless integration of the calibration mechanic, which could have affected the results of the study.

5.3.3 S3D Limitations

In stereoscopic cinema, the concept of depth budget refers to the actual distance between the closest object in the frame and the furthest object [27]. It is important that objects are not allowed to appear outside of the depth budget to create for a comfortable experience. The study allowed for the participants to change the interaxial separation value (by increasing or decreasing the distance between the centres of the two camera lenses) which resulted in either greater or less depth. The 1/30th rule is a common rule in stereoscopic film to determine what the maximum interaxial seperation can be, stating that the interaxial separation should only be 1/30th of the distance from your camera to the closest subject. Although the study abided by the 1/30th rule when the player was running, the player actually exceeded the 1/30th rule when they would jump, creating negative parallax. This could be a reason for the uncomfortable experience many participants had discussed in their free-form comments. The 1/30th rule is also not a confirmed rule, but simply a rule-of-thumb so there is no guarantee that it will work in every situation [27].

Prior research also suggests that motion in depth, (i.e., the magnitude of binocular disparity varying over time) could play an important role in visual discomfort [95]. Furthermore, it has also been suggested that both planar motion as well as angular disparity between foreground object and background plays an important role in visual discomfort [62]. The study conducted in this thesis makes heavy and repeated use of both planar motion (in terms of a constant velocity as the camera has a constant forward velocity), and angular disparities (the difference of angles between the roofs of the buildings and the floor). Participants who could not fuse the images, due to visual discomfort, may have had minimal options between the stereoscopic values available for them to select from, simply because they had difficulties viewing the higher stereoscopic values.

5.3.4 Experimental Design

It should be noted that in terms of the experimental design, the groups performed the conditions in a defined order, the S3D lens method first, followed by the slider method. Since this was a consistent order throughout all of the tests, the S3D lens method could have influenced the final value that they selected in the slider method. This could have been avoided by counterbalancing the study so that half of the participants performed the S3D lens method first, while the other half of the participants performed the slider method first. There also was no wait period between the two trials, so instead of the user selecting a new value, they may unknowingly attempted to match their first condition. Enforcing a five minute wait period between trials, for example, may have indicated to the participants that they approach the second trial with no S3D preference.

Chapter 6

Spatial Learning with Stereoscopic 3D

6.1 User Study Measuring Learning in Stereoscopic 3D

As described in Chapter 1, the fire safety training game was used as a test-bed to conduct a study that examined the effect that stereoscopic 3D has on spatial learning. The objective of the study was to examine whether stereoscopic 3D can improve user performance within a virtual environment, specifically when conducting a task which required spatial awareness along the depth axis. In this chapter, an experiment is described where participants were trained the appropriate distance to keep from a fire (within a virtual environment), and were later tested (after a 24 hour period) on whether that spatial information was retained, and how well it was learned. A portion (half) of the participants were trained within a traditional 2D viewing environment while the other participants were trained within a stereoscopic 3D viewing environment, and the results of both groups were compared. The results of this study brings us closer to developing a greater understanding regarding the implications of stereoscopic 3D within serious games and virtual environments applied to learning and training.

6.1.1 Modifications for Experiment Purposes

The fire safety training game described in Chapter 3 was modified to examine depth-based interaction and more specifically, in the case of this game, proximity to a fire while navigating the level, and while extinguishing the fire. Two game levels were created for experimental purposes: one level was designed to teach users the safe distance to remain from a fire at all times, and a second level was designed to test a users retention level based on spatial tasks learned from the first level. In both levels, the procedure that the player had to follow to extinguish a fire was replaced. More specifically, the P.A.S.S micro-game was removed, allowing the players to spray fire retardant (from the fire extinguisher) by simply aiming the hose, which points in the direction that the user is facing, and pressing a button to squeeze the handle.

Each game mode also allowed for the switching between stereoscopic 3D and traditional 2D viewing, for experimental purposes as well. For the 2D viewing mode, although not necessary, the game was still rendered twice, using the same methods that are used for stereoscopic viewing, however the interaxial distance was set to 0 so that no stereoscopic 3D effect was present. This was done for consistency issues, since rendering the frames twice — which is required for stereoscopic viewing — may cause noticeable video lag.

Trial Level

The trial level of the game had to be different from the scenario mode, since the goal was to teach spatial information to the user, specifically the safe distance to remain from a fire while extinguishing it. In this level, all objects were removed, and the player was spawned in a small empty room with a checker-board texture applied to the floor, walls, and the ceiling (Figure 6.1). It was anticipated that by employing a checker-board texture, participants would be given a reference to better judge spatial information.

The player was spawned at the front of the room facing a fire extinguisher that was floating mid-air at the player's eye level. The player had to pick up the extinguisher and use it to extinguish a series of fires, under different conditions (i.e., in some instances the player was allowed to move, in others the player was told they were too far or too close to the fire, etc.). Initially, after the player picked up the extinguisher, a fire was spawned directly in front of the player at the safe distance. The player was locked into position and was forced to extinguish the fire, then another fire, also at a safe distance, was spawned to the left of the initial fire. The player extinguished a total of three fires while their movement was restricted. This was done to provide the player with a clear understanding of what a safe distance to the fire actually was.

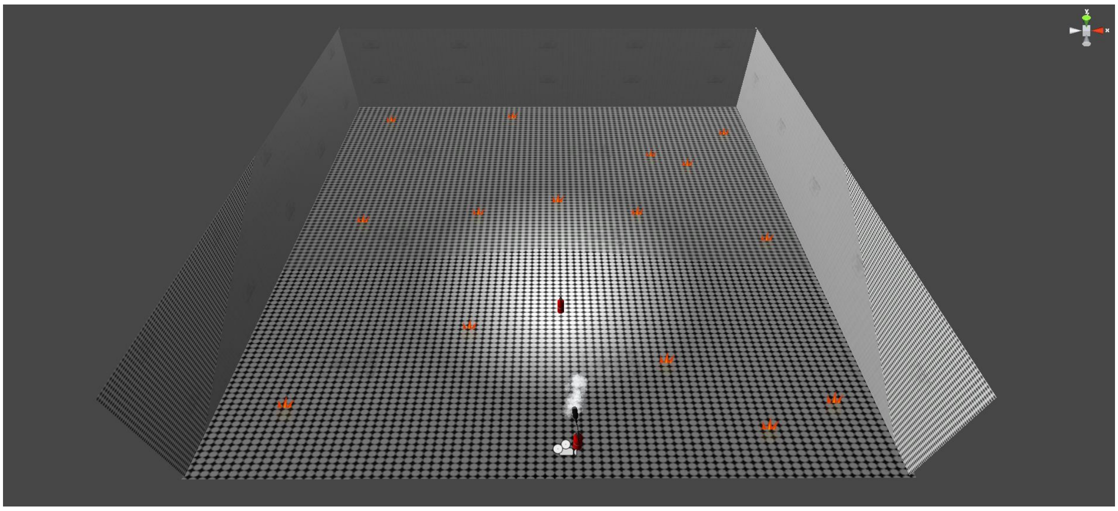

Figure 6.1: The trial level created to teach the safe distance to remain from a fire. Each fire node indicates the location where a fire would be spawned.

After the third fire was extinguished, another fire in one of the corners of the room was started and the player was prompted to move towards the fire and extinguish it, with movement controls now given back to the user. This was repeated for another two fires, allowing for a total of three fires with full player movement to precede the initial three fires with restricted player movement. For this set of three fires, the user was given hints about their location relative to the fire. On-screen text provided the user with information, letting them know whether they were too far from the fire. Furthermore, if the player was too close to a fire, a flashing red screen appeared to stress the imminent danger.

After this second set of three fires was extinguished, a third set of three fires was started. For this third set of fires, the user was no longer provided with information indicating whether they were too far from the fire, however their screen would still flash red if they were too close to the fire. Finally, after these three fires were extinguished, a fourth and final set of five fires was spawned at various locations throughout the room. For these final five fires, no hints were provided, and the player was required to estimate their distance to the fire based entirely on their spatial memory. The method of providing distance-related hints and gradually removing them from the user, was performed in an attempt to teach the user the appropriate distance without allowing the user to heavily rely on hints or extra feedback that are not available in the real world, nor in the testing level.

For each of the fires, the number of misses (foam particles which did not land on the fire), and the average distance (an average distance calculated by recording the distance the player was, relative to the fire, only while the player was actively

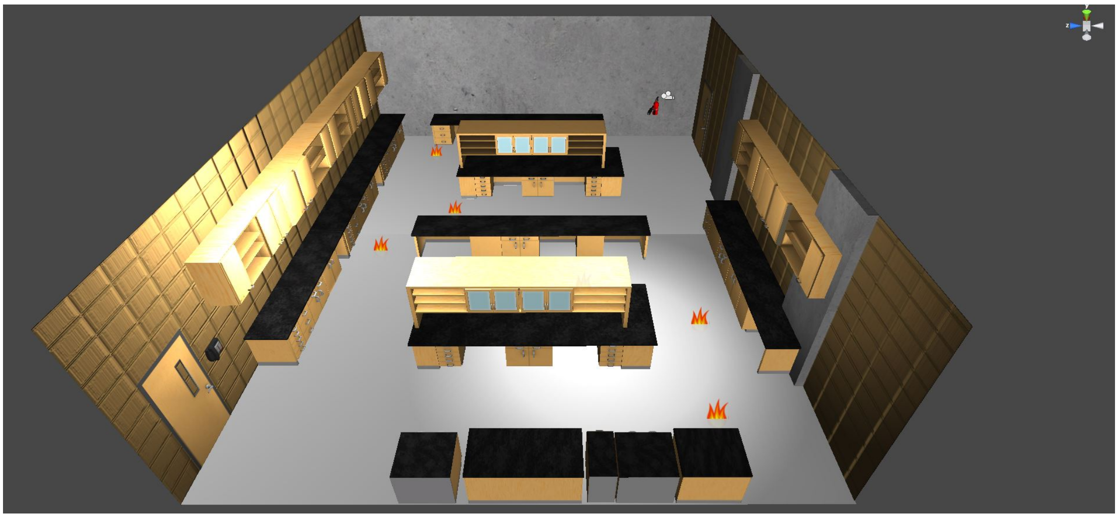

Figure 6.2: "The test level to evaluate how well a user learned the safe distances to remain from fires. Each fire node represents where a fire will spawn".

extinguishing the fire) was recorded. The position of all the fires in the trial level, although seemingly random, were pre-defined and were spawned in a consistent order for all participants for testing consistency.

Testing Level

A separate level was created to be played 24 hours after the trial level, to measure the knowledge retained by the participants after learning the ideal distances taught in the trial level. Similar to the trial level, all scenario gameplay was removed to allow the player to focus only on safe distances from fires. The same level from the scenario mode of the game (the chemical lab) was employed, however the total area of the room was increased by twice its original size and was populated with more of the same objects (Figure 6.2).

This was done to allow for more navigation space thus providing the player with multiple routes to reach each fire. The player was spawned to a corner of the room, this corner was the player starting position and was pre-defined and consistent between all plays. The player was then prompted by on-screen text to pick up the fire extinguisher and extinguish the fire. The extinguisher was placed on a wall in the opposing corner of the player's starting position. Once the player performed the task, they are re-spawned to the player start position and another fire in a different position was initiated. This was done to test whether the player chose the correct routes to reach each fire, since some routes forced the player to come into close contact with the fire. The fire extinguisher always remained in the opposite corner of the room and the player was required to pick the extinguisher up before extinguishing each fire. There were six fires in total for the player to extinguish, before completing this level. All of the fire positions were pre-determined and the order remained consistent throughout all the tests for testing consistency.

6.1.2 The Participants

The participants were comprised of 35 volunteer students from the University of Ontario, Institute of Technology (UOIT). These students ranged from a variety of programs, however the majority of participants (76.5 %) were enrolled in the Game Development and Entrepreneurship program at UOIT. The age of the participants ranged from 18-29, with the majority of participants (51.5 %) being between 21 and 23 years of age. One of the participants, after conducting the “Randot Stereotest” scored very low stereo acuity scores, and for the purpose of this study was deemed stereo-blind. The participant was informed they could no longer proceed with the study, and the sample size was thereby reduced to 34. Furthermore, two students were unable to return for the final session on the second day, thus resulting in 32 (out of 34) complete two-day sessions. It is important to note that of those 32 participants, three participants were female, and according to Schild et al. stereoscopic 3D can be perceived differently based on gender [88], so females were excluded from the final data set that was analysed to ensure consistency. This then forced the randomized removal of one of the data sets to balance the experiment, leaving a final sample size of 28. The experiment abided by the University of Ontario Institute of Technology Research Ethics Board Ethics Review process (R.E.B #11-004) for experiments involving human participants.

6.1.3 Experimental Method

Participants began by being seated in front of a desktop computer with and were informed of the experiment by the test administrator. They were then asked to complete a simple demographic questionnaire (see Appendix A.3). This was followed by a more specific game experience questionnaire whose purpose was to determine their level of experience with video games. This was to be used as a pre-test to ensure participants had entered the game with similar experiences.

After completing both questionnaires, the participant was given a “Randot stereotest” to ensure that the participant had normal stereoscopic depth perception. The Randot stereotest is just one of the many standard tests used by optometrists to measure stereo acuity, and is regarded as superior to other tests (such as the Titmus test, often used with infants since you do not need polarized glasses) due to its wide range of disparity presentations and lack of monocular cues [20]. If the participant passed the test, then they were allowed to continue with the study. Having abnormal stereoscopic depth perception would have skewed the results, since all participants were required to play in both modes.

The participants were then provided with greater details regarding the experiment and more specifically, they were provided with specific game details and information regarding the control scheme. The participants were asked to place active stereo glasses on, and to keep the glasses on at all times. Although the glasses were not required for 2D viewing, it was important for the participants to wear them regardless so that if there were any performance issues caused by the glasses, those issues would be present in both game modes. The trial level was then played, followed by a survey question asking whether the user perceived the game to be in 2D or stereoscopic 3D. The participant was then scheduled for a second test at least 24 hours after the first test occurred. Due to scheduling conflicts between the researcher and the participants, this retention period ranged anywhere from 24-30 hours after their first test.

On their second arrival the following day, the purpose of the experiment was re-iterated to them. After being instructed to wear their glasses at all time, participants played the test level of the game using the opposite of the viewing mode they had played during the previous day. After the game was completed, they were asked in an online survey whether they perceived the game to be in stereoscopic 3D or in traditional 2D. After answering the question, participants were instructed to play the test level one last time, but this time in the same mode that they had played the previous day. After the participant had completed their final play-through, the question of which viewing mode they had played in was asked once more. This was followed by a free-form comment section in which they were asked for any feedback regarding the experiment itself. The participants were then debriefed on the details of the experiment, and any remaining questions were answered. The experiment abided by the University of Ontario Institute of Technology Research Ethics Board Ethics Review process.

Quantitative Research

The design of the study was chosen to be a “cross-over design”, based on Pawlik et al. which was commonly used to asses new instruments and technology in the medical field [77]. In terms of a pre-test, a game experience questionnaire was

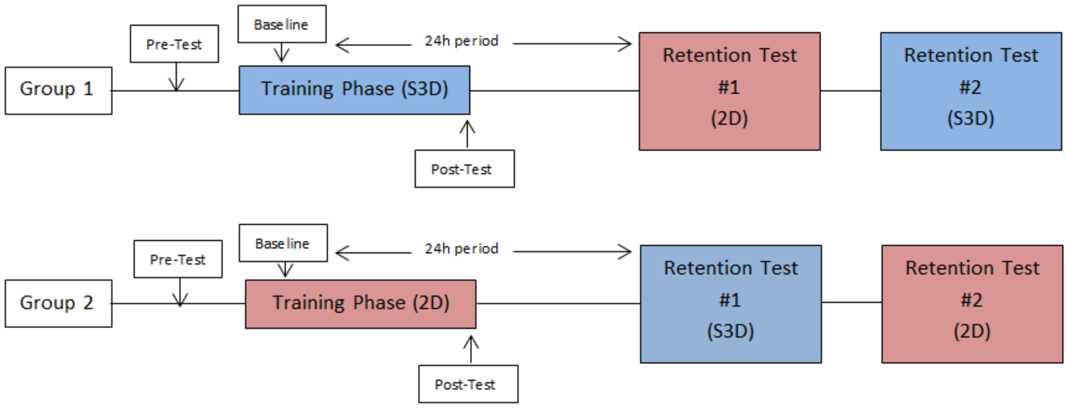

Figure 6.3: A flowchart displaying the experiment design for the spatial learning study.

provided to asses a users prior experience level with games. This was done to avoid a formal pre-test which may have contaminated the results, since it would act as an intervention [77]. A calibration phase followed which allowed the recording of a baseline test, which was the first "free-choice" fire in the trial (the first fire where the player was actually able to move to freely), and a post-test which was the final fire of the day. Since this was an immediate post-test, this would serve as a good indicator of performance improvement, but not necessarily any learning. To measure learning, we put in place a 24 hour retention period, followed by a retention test. Participants played in both 2D and S3D during their retention test, so that the learning effects could be evaluated for four separate groups.

1. Those who learned in S3D and were tested in 2D.
2. Those who learned in S3D and were tested in S3D.
3. Those who learned in 2D and were tested in 2D.
4. Those who learned in 2D and were tested in S3D.

A flow chart of the experimental design is provided in Figure 6.3.

6.2 Results

6.2.1 Participant Game Experience

Prior to beginning the experiment, participants were asked several questions regarding their prior video game experience. The majority of participants spent less than five hours a week playing video games (Figure 6.4). However, many participants stated that they had answered that question based on the demands of their current life, and outside of the school season, and therefore, spend many hours each week playing video games. While 100% of participants stated they had watched a movie, in stereoscopic 3D, 55.9% of the participants stated that they had previous experience playing stereoscopic 3D games (Figure 6.5). Also, participants had a similar preference for stereoscopic 3D games, as they did with stereoscopic 3D films, generally declaring that the content should be equally enjoyable whether in stereoscopic 3D or traditional 2D (Figure 6.6 and 6.7). Only 14.7% of participants owned a hardware device capable of allowing for stereoscopic 3D viewing. 82.4% of participants indicated that they owned a video game console, and the largest group of participants (46.1%) spent anywhere between $50 - $199 on console games in the past year (Figure 6.8). The results to additional questions regarding prior video game experience are available in Appendix A.3

6.2.2 Perception of Stereo 3D

After the trials were completed, the participants were asked whether the game was displayed in stereoscopic 3D (S3D) or in traditional 2D. In the first session, 83.3% of users answered incorrectly when viewing in traditional 2D mistakenly assuming that they were playing in S3D. After playing their second session in S3D, only 53.3% of users mistakenly recognized 2D for S3D in their third session. The second group, which had their first session in S3D, incorrectly mistook 2D for S3D in 76.5% of the responses. When playing the video game in S3D, the group that played their first session in S3D were all correct in recognizing that they were playing in S3D. That same group's final session which was played immediately after a 2D session, 100% of users were correct in perceiving that the game was in S3D. However, when the group who played their first session in 2D played their second session in S3D, 6.7% of users were incorrect, stating that the S3D game was actually in 2D.

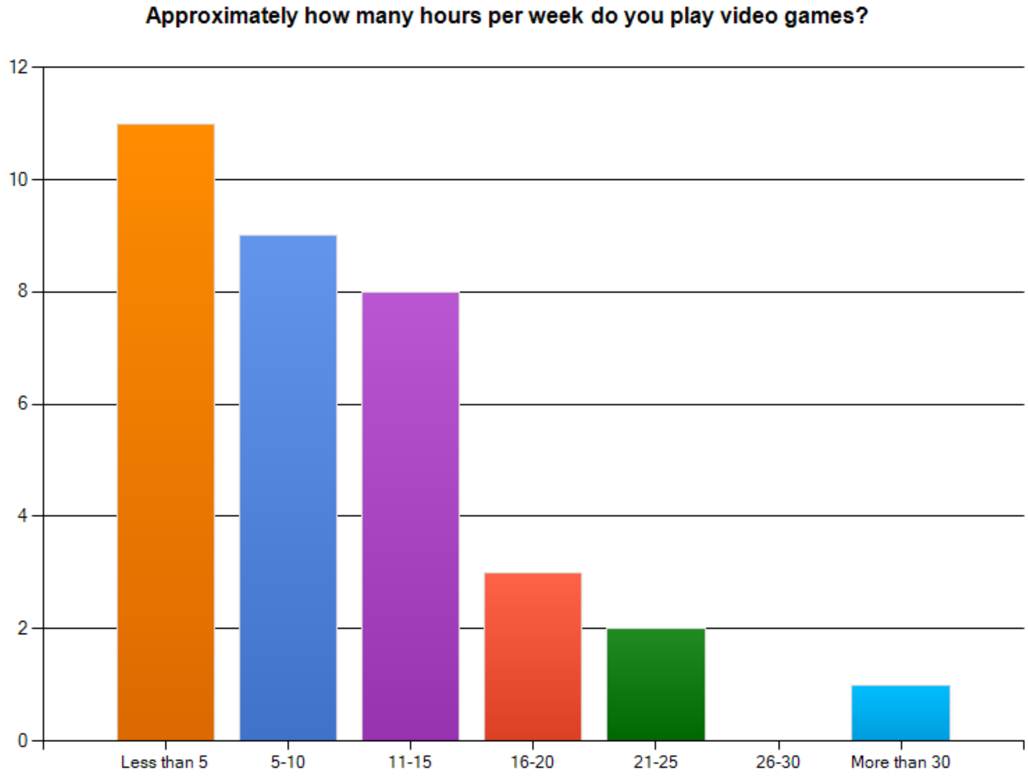

Figure 6.4: How many hours a week participants play video games.

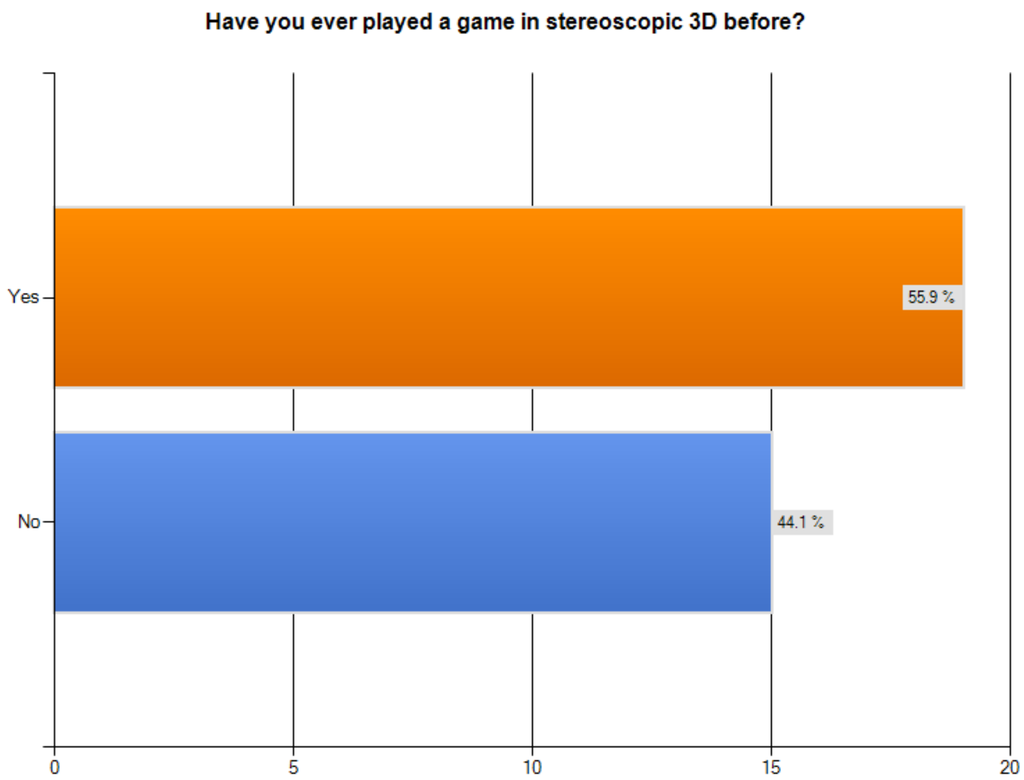

Figure 6.5: Participants' prior experience with stereoscopic 3D games.

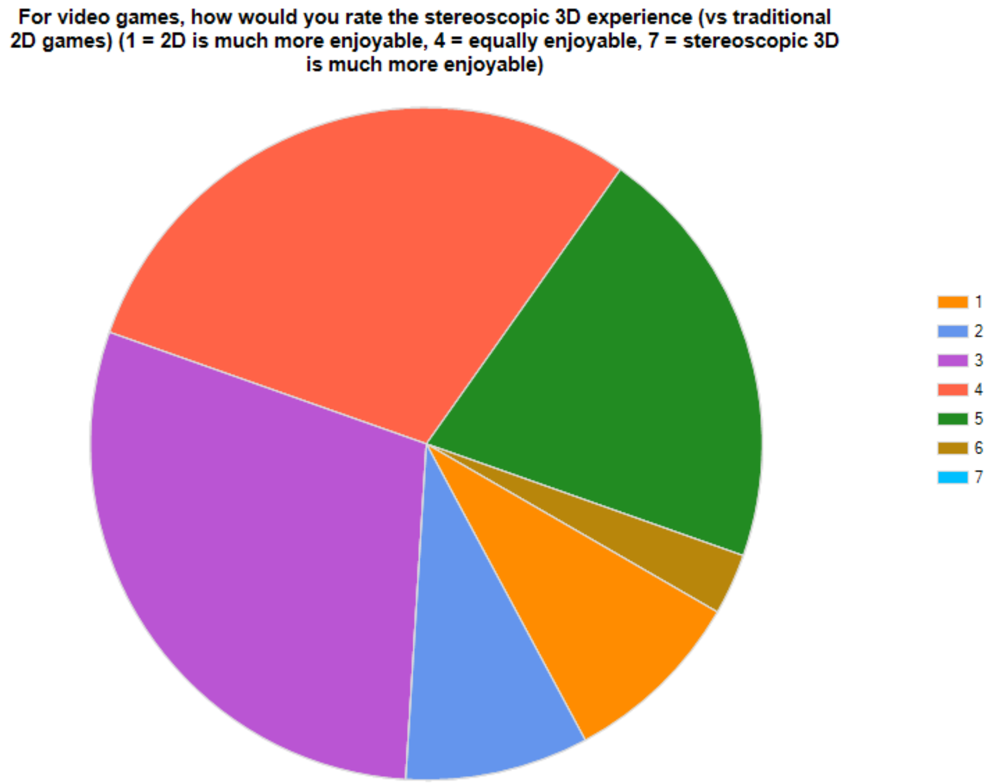

Figure 6.6: Participants rate their enjoyment of stereoscopic 3D vs. traditional 2D games, on a scale of 1 to 7, where 1 is "2D is much more enjoyable" while 7 is "S3D is much more enjoyable".

6.2.3 Experimental Results

Learning Effects

To analyse the data, four separate groups were examined based on the viewing condition that they had performed the trial in, and the viewing condition they had performed their retention test in. The four groups were:

1. 2D training with 2D retention (2D-2D).
2. 2D training with 3D retention (2D-3D).
3. 3D training with 2D retention (3D-2D).
4. 3D training with 3D retention (3D-3D).

The multivariate analysis of variance (MANOVA) was selected as the statistical model with two factors: the four groups based on the players viewing environment

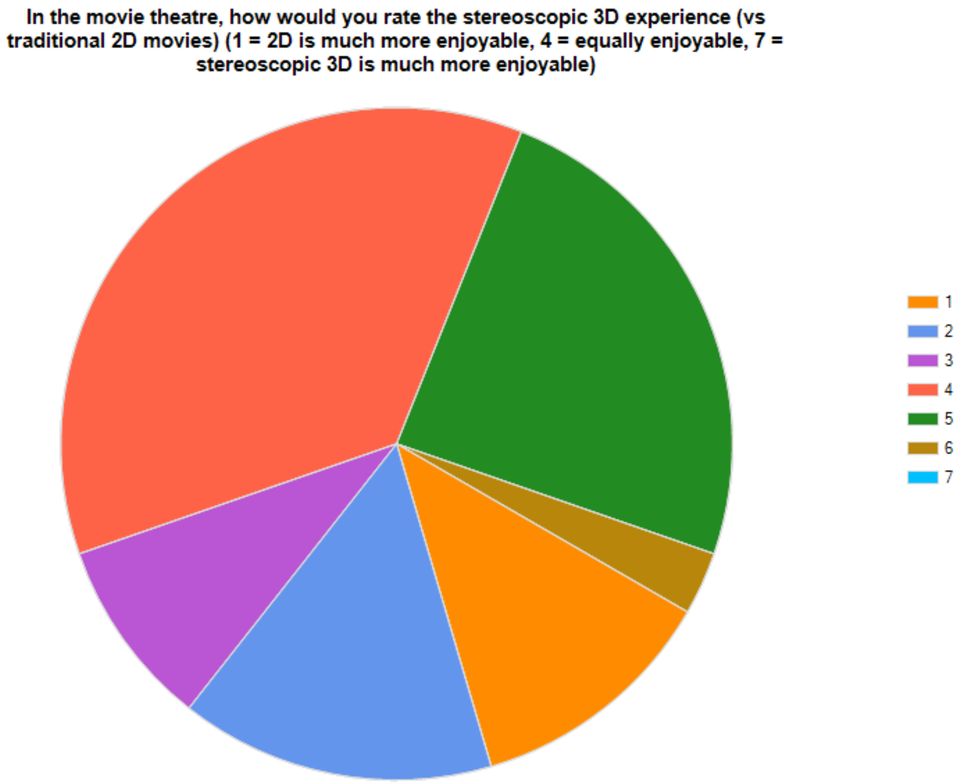

Figure 6.7: Participants rate their enjoyment of stereoscopic 3D vs. traditional 2D movies, on a scale of 1 to 7, where 1 is "2D is much more enjoyable" while 7 is "S3D is much more enjoyable".

in each the training and retention test × three tests: i) baseline test, ii) post-test, and iii) retention test. The dependent variables were average distance and accuracy. The results of the two way MANOVA (group by test) revealed only significant main effects for the test, Pillai's Trace = .708, F = 28.337, df = (310), p = .01, indicating differences between the baseline test, post-test and retention test for all the dependent variables. There were no significant differences for group or the interaction between the factors (group by test) (see Appendix B.4 and Appendix B.2).

The one interaction was further analysed by two subsequent one-way ANOVAs with test as a factor, for each of the dependent variables. The analysis for accuracy revealed significant results for the test (F=6.03, df= 2, p= 0.03). Subsequent post-hoc comparisons (LSD) revealed that baseline test's scores have a significant difference when compared to the post-test and retention test ($p<0.02$). Results of our study, with regards to accuracy are summarized in Figure 6.9, which displays the accuracy of each individual group analysed over the entire study, in their baseline test, post-test and retention tests. These results are also summarized in

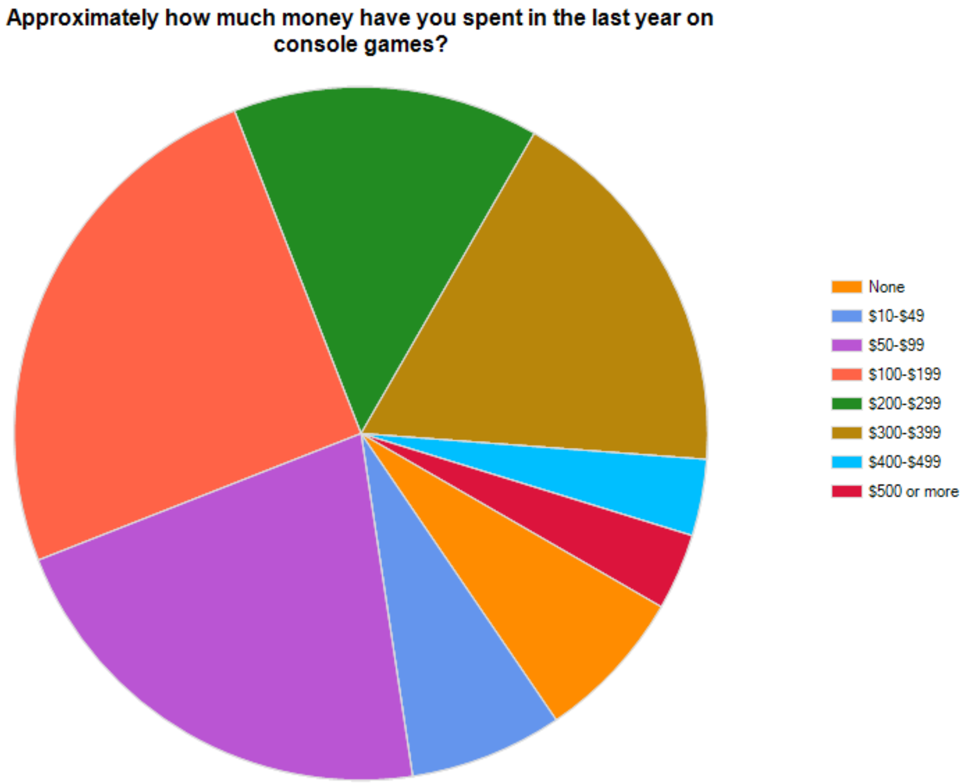

Figure 6.8: How much money participants spend on video games every year. The majority of participants spent an average of $100 - $199 on video games last year.

Appendix B.3 clearly indicating that all groups improved their accuracy between the baseline test and the final retention test.

The analysis for average distance revealed significant results for the test (F=31, df= 2, p=0). Subsequent post-hoc comparisons (LSD) revealed that retention test scores have a significant difference when compared to post-test and baseline test (p=0). Results of this study, with regards to average distance are summarized in Figure 6.10, which displays the average distance of each individual group analysed over the entire study, in their baseline test, post-test and retention tests. These results are also summarized in Appendix B.1. Essentially, the mean distance declines further away from what was originally taught, and players started extinguishing the fire closer than what was taught to them in their training session.

A paired samples t-test was also conducted to examine the variables that were not explicitly practised in the training session. In this case, the performance of individuals with respect to their retention test based on their learning condition, (whether in 2D or S3D) was analyzed. A paired-samples t-test was conducted to compare the players elapsed time based on their learning condition (whether they

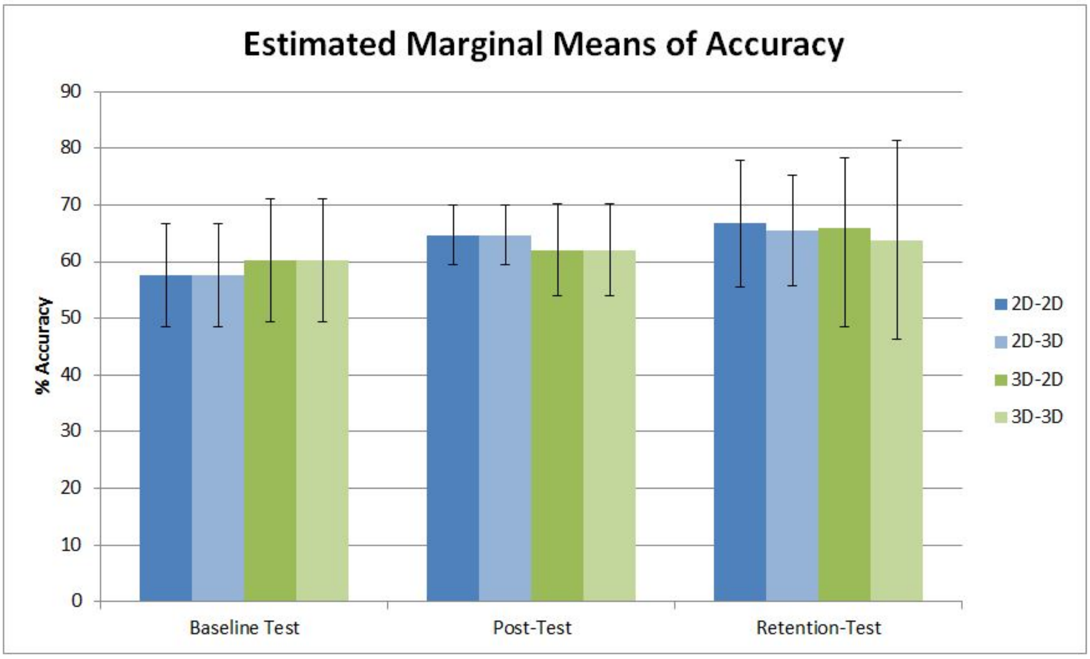

Figure 6.9: Experimental results showing accuracy improvements after training for every group that was analysed. Graph represents % accuracy vs. group, including error bars to represent standard deviation.

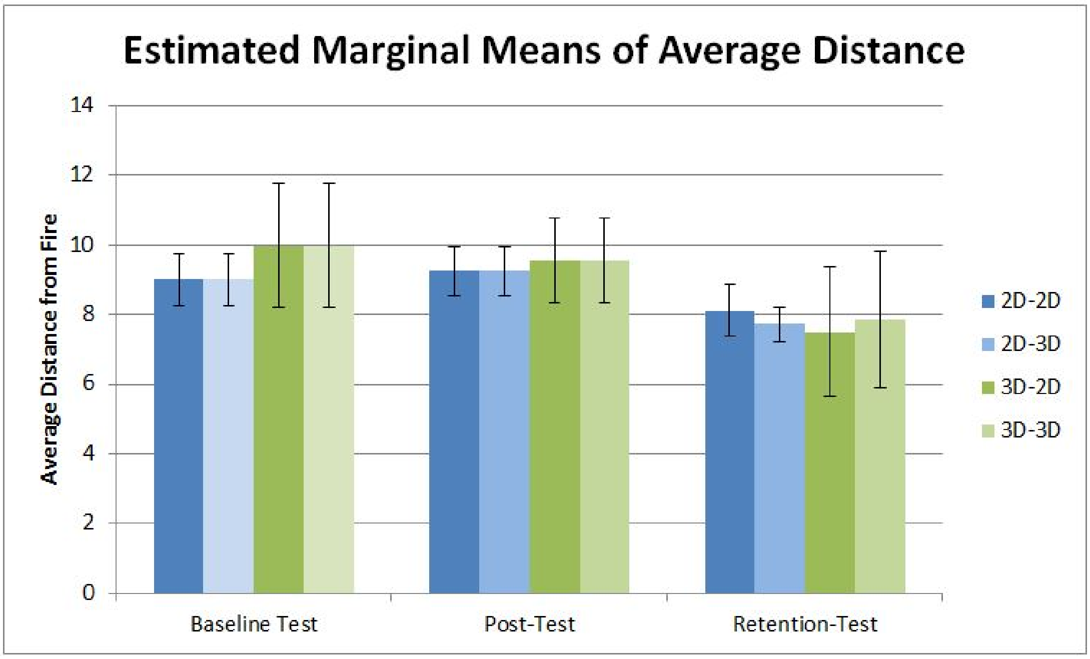

Figure 6.10: Experimental results showing average distance amongst each group that was analysed. Graph represents average distance vs. group, including error bars to represent standard deviation.

learned in 2D or S3D). There was no significant difference in the scores for those who learned in S3D (M=30.1, SD=8.78) and those who learned in 2D (M=29.62, SD=6.11) conditions; t(167)=1.168, p=0.108. These results suggest that learning in stereoscopic 3D or non-stereoscopic 3D viewing conditions have no effect on a players performance (how fast the player completed the task).

A paired-samples t-test was also conducted to compare the players number of collisions based on their learning condition. There was no significant difference in the scores for those who learned in S3D (M=4.02, SD=1.8) and those who learned in 2D (M=3.92, SD=1.97) t(167)=0.488, p=0.626. These results suggest that learning in stereoscopic or non-stereoscopic viewing conditions have no effect on the amount of times a player collides with an object, which can be understood as having no effect on a players navigation within a 3D environment.

A paired-samples t-test was also conducted to compare the amount of time a player spent collided with an object based on their learning condition. There was no significant difference in the time spent for those who learned in S3D (M=6.15, SD=4.84) and those who learned in 2D (M=6.52, SD=5.51) conditions; t(167)=-0.708, p=0.480. These results suggest that learning in stereoscopic or non-stereoscopic viewing conditions have no effect on the amount of time a player spends collided with an object, which also further points to having no effect on a players navigation within a 3D environment.

A paired-samples t-test was also conducted to compare the amount of damage a player takes from being too close to a fire based on their learning condition. There was a significant difference in the scores for those who learned in S3D (M=257.23, SD=298.45) and those who learned in 2D (M=203.15, SD=242.66) conditions; t(167)=2.079, p=0.039. These results suggest that learning in stereoscopic or non-stereoscopic viewing conditions has an effect on the amount of damage a player takes from being too close to a fire. More specifically, with a group trained in S3D, players take on more damage from fires, by being too close to the fires continually throughout their testing than those who trained in 2D.

User Performance Results

Aside from the analysis between tests, another test was conducted using the data collected in the retention test only. This allowed for the investigation of user performance issues between the variables that were only present in the retention tests. Paired sample t-tests were conducted for all the variables recorded in the retention test, which were: elapsed time, time collided, and health.

Group 1 Results of User Performance

Paired sample t-tests were conducted separately for each group, those who learned in 2D and those who learned in S3D. In terms of Group 1, which was the group that learned in 2D, a paired-samples t-test was conducted to compare the players elapsed time in S3D and 2D conditions. There was a significant difference in the scores for S3D (M=30.37, SD=7) and 2D (M=28.88, SD=5) conditions; t(83)=2.146, p=0.035. These results suggest that stereoscopic or non-stereoscopic viewing conditions have an effect on a players speed and more specifically, our results suggest that with a group trained in 2D, players perform faster in 2D than in S3D.

A paired-samples t-test was also conducted to compare the amount of time a player spent collided with objects in S3D and 2D conditions. There was no significant difference in the scores for S3D (M=6.53, SD=5.42) and 2D (M=6.51, SD=5.63) conditions; t(83)=0.038, p=0.970. These results suggest that stereoscopic or non-stereoscopic viewing conditions do not have an effect on the time players spend colliding with objects.

A paired-samples t-test was also conducted to compare the amount of fire damage taken by a player in S3D and 2D conditions. There was a significant difference in the scores for S3D (M=246.12, SD=247.56) and 2D (M=160.19, SD=231.21) conditions; t(83)=3.014, p=0.003. These results suggest that stereoscopic or non-stereoscopic viewing conditions have an effect on the amount of damage players received from being too near to a fire. More specifically, with a group trained in 2D, players take less damage in 2D than they do in S3D.

Group 2 Results of User Performance

In terms of Group 2, which was the group that learned in S3D, a paired-samples t-test was conducted to compare the players elapsed time in S3D and 2D conditions. There was a significant difference in the scores for S3D (M=29.24, SD=7.2) and 2D (M=32.35, SD=9.94) conditions; t(83)=4.153, p=0. These results suggest that stereoscopic or non-stereoscopic viewing conditions have an effect on a players speed, and more specifically, with a group trained in S3D, players perform faster in S3D than in 2D.

A paired-samples t-test was also conducted to compare the amount of time a player spent collided with objects in S3D and 2D conditions. There was no significant difference in the scores for S3D (M=5.81, SD=4.3) and 2D (M=6.5, SD=5.33) conditions; t(83)=1.095, p=0.277. These results suggest that stereoscopic or non-stereoscopic viewing conditions do not have an effect on the time players spend colliding with objects.

A paired-samples t-test was also conducted to compare the amount of fire damage taken by a player in S3D and 2D conditions. There was a significant difference in the scores for S3D (M=222.26, SD=271.95) and 2D (M=292.19, SD=320.6) conditions; t(83)=2.85, p=0.006. These results suggest that stereoscopic or non-stereoscopic viewing conditions have an effect on the amount of damage players received from being too near to a fire. More specifically, with a group trained in S3D, players take less damage in S3D than they do in 2D.

6.3 Discussion

6.3.1 User Feedback

A free-form comment section was available to the applicants on the end of both the training and retention sessions. On the first day (training day), many participants who ran the test in 2D, assuming they were playing in stereoscopic 3D, complained that the stereoscopic was not useful, or not noticeable. Some comments about the lack of 3D were:

> "The 3D did not help, I used the size of the object and its relation to the textures on the ground to judge distance". (Participant A17, March 2013).

> "The 3D effect was not very strong.". (Participant A16, March 2013).

> "Depth need to be more defined to call that 3D.". (Participant A14, March 2013).

It was clear to many users of that 2D group that there was very little to no stereoscopic 3D effect, however according to the other questions answered on the survey, they still erred on the side believing it was stereoscopic 3D, albeit not very effective stereoscopic 3D. This may have been attributed to the fact that they were forced to wear stereoscopic 3D glasses the entire time, and the dimmed viewing of the monitor caused by the stereoscopic 3D glasses may cause participants to infer that the visuals were in S3D. This may have lead to a novelty affect in which the users performed more carefully due to the 3D glasses, assuming they were playing within a stereoscopic 3D environment, when they were not. No comments were made about the lack of 3D from the group that played their first session in stereoscopic 3D. Some users also never fully utilized the distance feedbacks provided in the first session. This was confirmed by some user comments:

> "I always felt the need to be cautious and stay at far from the fire as possible; I never had a flashing red screen because I was afraid to get too close.". (Participant B14, March 2013).

> "I never receieved a flashing red screen.". (Participant B10, February 2013).

Some users also had issues with the feedback, saying it occluded the more important game information. Some comments were:

> "When told that i was too close to fire, the sign blocked the fire and made it hard to judge distance.". (Participant B01, February 2013).

> "Text warnings were in the way and made it hard to measure distance at first.". (Participant B13, March 2013).

This may have caused issues with learning appropriate distances with the earlier fires (the first six), the text may have occluded the region between the player and the fire, which is the same area that the user was required to look at to determine their distance. Another area of complaint was that some of the fires may have spawned too close to the players current position. Some examples of comments that displayed this were:

> "Fire spawned on me, which made it a tad more difficult.". (Participant B13, March 2013).

> “Sometimes the fire appeared randomly right beside me and I didn’t have control of being to close to the fire at that point.”. (Participant A1, February 2013).

However, it is assumed that this had minimal (if any) impact on the data recorded, since the average distance of the player was only recorded if they were actively using the extinguisher. The controls of the game were found to be

> “Fluid and responsive.”. (Participant B08, February 2013).

by one user, stating that they had an easier time with the controls in this game than in a AAA game. One user however found the game to be too slow, saying

> “I found the movement of the player to be rather slow...”. (Participant A11, 2013).

This was similar to what Smith et al. had discovered when many users found the movement of the player in their game frustratingly slow [94]. Although the movement speed in the game was fairly accurate in terms of average human walking speed, many of the complaints came from experienced players who are used to a much faster (and unrealistic) movement speed, common to commercial games. Overall, many participants who left feedback after the first session made many positive comments about the game. A sample of the positive comments:

> “Fun experience.”. (Participant B09, March 2013).

> “Good teaching tool.”. (Participant B03, February 2013).

> “Learning experience was good.”. (Participant A03, February 2013).

> “I got a good understand of the appropriate distance needed to put out a fire safetly.”. (Participant A03, February 2013).

and another participant who played the game in stereoscopic 3D claimed the viewing mode provided them with a heightened spatial awareness. On the second day of testing many users re-iterated their same comments from the first day, although there was a much larger display of frustration in terms of the player movement. Users stated

> "Sensitivity too low.". (Participant A03, February 2013).

> "Turn speed was a little low.". (Participant A15, March 2013).

> "Slow moving need sprint button.". (Participant B06, February 2013).

This may have been due to the fact that the testing level that the users played on the second day required much more navigation due to the addition of other obstacles, so there was more movement overall. Some users also stated that they had remembered what they had learned from their trial session, a day prior. Some user comments confirming good knowledge retention were:

> "Remembered the testing day alittle but once i started to play the game then it started to come back to me.". (Participant A14, March 2013).

> "The experiment from the day before was engraved in my head.". (Participant B15, March 2013).

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6.3.2 User Learning

The main hypothesis of the study was that users who learned a spatial task in an stereoscopic 3D virtual environment would have a higher retention level than those who learned in a 2D virtual environment. To study this, four different groups were created by looking at each retention test individually. This allowed for four groups: those who ran the trial test in S3D and its effects on a retention test in 2D (Group 1), those who ran the trial test in S3D and its effects on a retention test in S3D (Group 2), those who ran the trial test in 2D and its effects on a retention test in S3D (Group 3), and those ran the trial test in 2D and its effects on a retention test in 2D (Group 4).

However, the results of this study have shown no significant difference between any of these groups, determining that the viewing method does not effect knowledge retention, with regards to spatial tasks. These findings contradict what was proposed by prior research, primarily Bennett et al. who suggests that stereoscopic

3D leads to more vivid memory experiences within a spatial task, and therefore should have lead to higher retention levels [7].

However, this could be related to the fact that the task itself may have had motion as the dominant cue, as opposed to stereopsis. Since participants were able to move along the depth cue, they may have been using different cues more strongly, such as the scale of the object that they approached, which allowed for a lower reliance on the stereopsis cue itself.

Although there were no significant difference between the groups, our data does show a relationship between groups when looking at average distance scores. Analysing the average distance scores reveals very little difference between the mean average distance between tests when the retention test was performed in S3D. This could point to a vetoing theory in terms of visual cue theory, since users may be using the stereopsis cue identically regardless of which environment they learned the safe distance in. In addition, users who learned in 2D perform better in 2D, than those who performed in S3D (See Figure 6.11).

Results also indicate that users performed better in their retention test than they did in their post-test, when looking at accuracy scores (Appendix B.3). This could be explained by the environment itself, since the environment, a chemical lab, was more context-appropriate in the testing phase (retention tests) than the training phase (baseline and post-test). Bennett et al. had similar results when comparing their abstract test to their contextual (office-setting) test [7]. The environment that the user was placed in may have had an effect on their performance, since one offers more fidelity. Furthermore, the participants were instructed that their first day was simply a training phase, so they may have put in less effort on that day. The second day they were instructed was a testing phase, which may have lead to gameplay with more effort.

This may be explained by the specificity of the practice proposed by Proteau et al. which is the idea that learning is specific to the conditions that prevail during skill acquisition [79]. In simpler terms, users who were trained in 2D will perform better in 2D since it is the environment they were trained in. In terms of the group that learned in 2D and performed the retention test in S3D, they had perceived the fire to be the furthest from themselves by the largest margin compared to all the other retention test scores. This seems to go coincide with prior research performed by Tai et al. in their conclusion that S3D causes an over-estimation of depth [98].

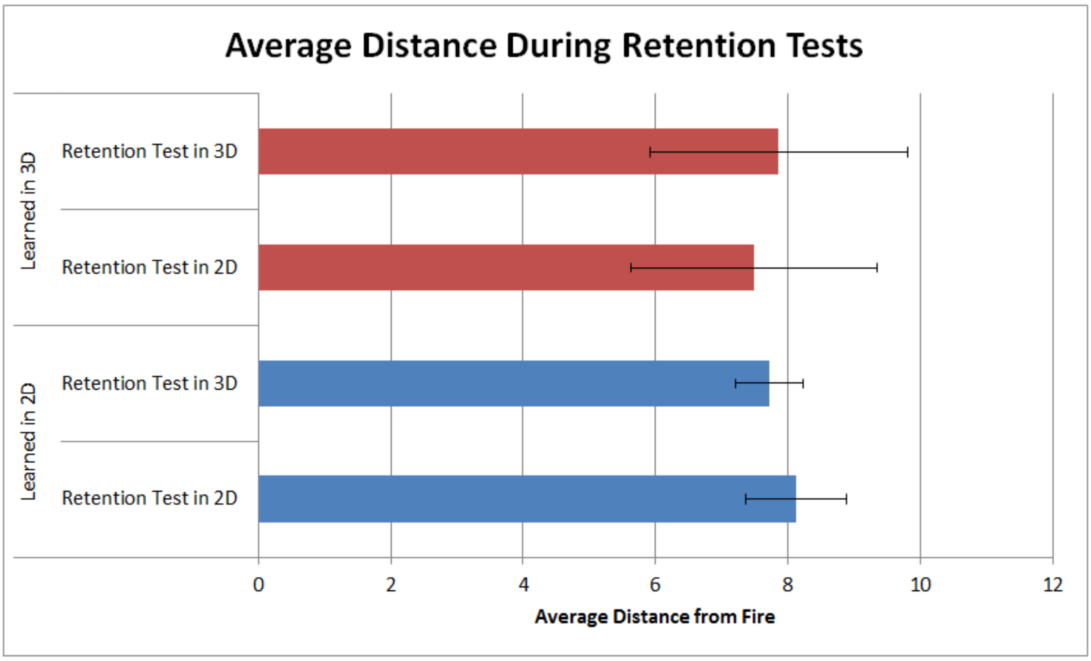

Figure 6.11: Relationship shown between distance scores amongst the four groups, including error bars to represent standard deviation.

6.3.3 S3D Limitations

It is important to address some of the limitations of the experiment that may have affected the results of the study. The stereoscopic 3D cues presented in the game may not have been "deep" enough, or have a large enough interaxial distance between the two stereoscopic images to cause that great of an effect. Although our user feedback states that the S3D was both helpful and noticeable (when it was active), the free-form comments seem to also contradict the amount of users that incorrectly assumed they were playing in S3D when in fact they were playing in 2D. This may have been due to the dampening of the S3D effect due to the nature of the game. Since this was a first-person shooter (e.g., the virtual world was observed from the user's avatar perspective) game, the fire extinguisher was placed at the plane of the player, and any changes to the scene's depth had a very noticeable difference on the extinguisher as well, since it was in the negative parallax space, which is known to cause greater discomfort. This is seen in many commercial first-person shooters as well, such as Killzone 3. It was proposed by Sony, in the development of Killzone 3, to render the gun on top to avoid the discomfort caused by the intense negative parallax of the gun if the entire scene was rendered together [87]. A similar method could have been employed for the fire extinguisher in the game.

6.3.4 Experimental Design

The experiment was designed to enable the analysis of four different groups. However, due to limitations regarding the number of participants, a between-subjects experimental design was used whereby each participant is tested under one condition only (i.e., with stereoscopic 3D or no without stereoscopic 3D). A between-subjects design offers many benefits such as reducing the amount of independent variables introduced by having many subjects, while still maintaining a statistical significance. Although each participant had a single baseline test and post-test, it was followed by two unique retention tests, allowing for the interpretation of two separate groups: baseline test, post-test and retention test 1, and baseline test, post-test, and retention test 2. The addition of those extra retention tests however could have potentially influenced the amount of learning that occurred based on the actual educational intervention [77]. The results of the second retention test in each case may have been influenced by many transient factors such as fatigue, boredom, or excitement.

Furthermore, since the second retention test was played immediately after the first retention test, this may have been more of an indication of immediate performance improvement rather than actual learning. Although, when looking at the average distances in figure 6.11), Group 2 performed identically to Group 3, even though Group 2 was a first retention test, and group 3 was a second retention test. This suggests that the second retention test was not affected by the first retention test. To avoid this problem entirely, ideally four separate participant groups should have been created, in which each group plays only one retention test. It would also be important to ensure that the compared participants of that proposed study shared similar baseline test and post-test scores, since skill levels must be identical for that type of comparison. However, as previously discussed, this would result in a much higher number of required participants and given that participants were not compensated (i.e., they volunteered to participate in the experiment), it would be difficult to recruit the required participants.

Chapter 7

Conclusions

Given the importance of incidence response education and training, it was decided to leverage the benefits of serious games by investigating the development of an interactive serious game for the purpose of incidence response procedure education and training. Virtual simulation and serious games can be an effective strategy for incidence response training as they offer a viable, economic, and safe alternative to the current training methods and techniques and are generally far more engaging than traditional training techniques. Currently, at institutions such as universities, proper fire safety is difficult to teach due to both economical issues as well as issues with distribution. An area of particular risk are chemical labs due to the inherent issues with hazardous and flammable chemicals that are both handled and contained within a university chemical lab. A serious game was created to teach and train the proper protocol for a chemical lab fire. The fire safety training game was created to aid and educate chemical lab instructors in an institutional environment. Although the game would be beneficial to be played by anyone exposed to hazardous chemical fire situations, it was created specifically with an instructor within a typical university lab in mind since they are the designated fire marshals in case of fire and they are responsible for upholding safe protocols in case of emergency. The game presents the user with multiple hazardous scenarios in which the user must react in the safest manner. It also teaches both proper fire extinguishing techniques as well as safe distances to remain from a fire. The game was developed to supplement current traditional education practices (such as fire drills and training courses), and is intended to motivate users by providing them with a fun, interactive, and engaging method of practising and familiarizing themselves with lab fire safety protocol. There have been a number of new technologies introduced to improve user engagement and knowledge retention in serious games. At the forefront of these new technologies is stereoscopic 3D viewing, which, in recent years, due to technological advances has become affordable and widely available at the consumer level. Within the scope of this thesis, it was decided to leverage stereoscopic 3D viewing techniques in the fire safety training game and examine performance issues and retention levels, to determine if stereoscopic 3D viewing is beneficial for users of serious games.

An initial study was conducted to determine whether playing a game viewed in stereoscopic 3D was more engaging than the same game viewed in traditional 2D. Using Frozenbytes' Trine, a 2.5D side-scrolling action game, it was determined that participants did not find the game more engaging in stereoscopic 3D according to their Game Engagement Questionnaire (GEQ) results (a questionnaire commonly used to determine a game players engagement in a game [12]). This result is consistent with prior work, most notably Schild et al. who report that users did not find any difference between games played while employing stereoscopic 3D viewing and traditional 2D viewing, if the game does not utilize the depth axis for gameplay [88].

It was also discovered that calibrating the game to offer the best stereoscopic 3D experience was very subjective (e.g., user dependent), and many participants may have been dissatisfied by their stereoscopic experience, not due to the stereoscopic 3D effect, but rather, due to settings that may have not suited them, since S3D is perceived uniquely by each user.

A second study that examined the calibration of stereoscopic parameters/settings was conducted. In this study, a novel calibration method was created and compared with a common slider-based approach. The results of the study revealed no significant difference between the novel method created and the traditional slider method. These results allow developers to utilize this seamless calibration method, which essentially allows players to dictate their stereoscopic 3D settings as part of their gameplay (by using a method inspired by standard testing methodologies utilized by optometrists). Moreover, it was discovered just how important proper stereoscopic 3D settings were to the enjoyment of the content. Although the calibration technique proposed within the scope of this study does not have a proper place in the fire safety game, it was important to understand how critical stereoscopic 3D calibration is to an engaging experience. Essentially, developers who plan to utilize stereoscopic 3D in their serious game to increase engagement must be weary of stereoscopic 3D calibration techniques and allow for an intuitive, simple way for participants to personally adjust their own settings.

Finally, a third study was conducted using the fire safety game as a test-bed to examine knowledge retention with regards to a spatial task and whether retention is dependent on different viewing methods (e.g., stereoscopic 3D vs. non-stereoscopic 3D). Users were required to learn the safe distance to remain from fires in either stereoscopic 3D or traditional 2D (non-stereoscopic 3D), and were tested on whether they retained this information after a 24 hour period. Although it was hypothesized that participants would perform better when the distances were learned in stereoscopic 3D, results revealed that there was no significant difference when comparing final scores between either viewing method. However, a slight relationship did show that developers must be aware of the specificity of practice, in that participants who learned in 2D performed better in 2D. These results show that although past literature suggest that stereoscopic 3D can lead to higher knowledge retention, there is in fact no significant difference between learning in 2D or learning in S3D.

Collectively, the results of these studies suggest that stereoscopic 3D has been ineffective in the scenarios considered in the scope of this thesis. Stereoscopic 3D viewing may not necessarily allow for a more engaging game experience in a game that does not consider the depth axis. Furthermore, developers must work hard to ensure the downfalls of stereoscopic 3D, such as calibration settings, and breaking certain stereoscopic 3D comfortability guidelines, do not interfere with the game and thus create an experience that is than its 2D counterpart. Also, in the third study presented, participants did not retain knowledge any differently when training/practising within a stereoscopic 3D viewing environment than they did in a 2D viewing environment.

In summary, developers should be careful about incorporating stereoscopic 3D viewing in games that do not make use of the depth axis. Furthermore, although greater work remains, the results of the study presented here indicate that knowledge retention is independent of the viewing environment and more specifically, a stereoscopic or non-stereoscopic 3D ("normal" 2D viewing) viewing environment will lead to the same result. Finally, it should be noted that many of these results come from experiments that disallowed users from calibrating their own stereoscopic 3D settings (for consistency purposes) which may have played a major role in the outcome of this thesis. As seen in free-form comments in all three studies, stereoscopic 3D is perceived differently by each user, adding subjectivity to each of the studies. It is the opinion of the author that further studies must be conducted to examine the effectiveness of S3D in a serious game (see Chapter 7.2), but aside from prior literature, the studies presented in this thesis offer no evidence for any advantage in favour of serious games using stereoscopic 3D viewing.

7.1 Contributions

This thesis describes the development of a serious game for incidence response training, specifically, chemical lab fire safety training. In addition, three separate studies were conducted to measure the significance of stereoscopic 3D and its effect on serious games. Firstly, it was determined when looking at games that do not take place along the depth axis, stereoscopic 3D viewing offers no more engagement than traditional 2D viewing. Secondly, it was determined that users must be given control over stereoscopic 3D calibration settings to enable a playable environment. Finally, it was determined that stereoscopic 3D viewing provides no significant advantage over traditional 2D in terms of knowledge retention. Collectively, the results of these three studies are very important to designers and developers of serious games. It is suggested that developers refrain from utilizing stereoscopic 3D in games that do not make use of the depth axis, neither should developers assume retention levels will be increased due to the use of stereoscopic 3D. Also, if a developer is planning on providing stereoscopic 3D support, the user should be given access to modify their own stereoscopic 3D settings, which is critical to the user's comfortability. Finally, the incidence response training game developed within the scope of this thesis, will be used by industry partners to supplement current chemical lab fire safety curriculum in the educational sector.

7.2 Future Plans

Many studies can be conducted to further explore the effectiveness of the chemical lab safety game. Firstly, it was concluded in the first study that stereoscopic 3D does not increase engagement in a game that makes no use of the depth interaction, however, no formal study in this thesis was conducted on a game that makes use of the depth interaction such as the fire safety training game. A formal study on the fire safety training game itself and its effects on player engagement may be interesting to confirm the results by Schild et al. which state that S3D can increase player engagement in a game which makes use of the depth axis.

Furthermore, examining the effects of other immersive technologies, such as whether haptic devices increase knowledge retention in a fire-extinguishing task, specifically looking at motor skills is planned for future studies. In addition, a study examining knowledge transfer can be conducted, that will investigate real-world knowledge transfer from a virtual game experience. The study would require a participant to learn specific scenario-based protocols within the serious game, and later the participant would be tested on whether their knowledge transfers to a real-world simulated scenario.

7.2.1 The chemical lab fire safety game

In addition to testing the effectiveness of the chemical lab safety game as an educational aid by running additional studies, there is also plans to improve its overall playability and effectiveness. One of the key features to be improved is the current non-player characters (NPCs). As the game currently stands, NPCs are used to represent other personnel in the same chemical lab. Currently they are simple static models that do not animate or move. Furthermore, when the user is asked to evacuate the room of personnel, the player approaches the NPCs and presses an "action" key, but the models disappear instead of evacuating the room. Future work will see the creation of an animation so that all NPCs can individually evacuate the room, which would remain more consistent with a real life scenario. NPCs can also be extended in future iterations with full artificial intelligence (AI) behaviours, so that the they act as people normally would in that environment (i.e., they may wander towards a desk and stand in front of it as if they were working).

Another feature to be developed in future iterations is a higher level of customizability for educators to utilize. Currently, most of the feedback given to the user is received by on-screen text; however if the text needed to be changed, an expert developer would need to be part of the customization process. Instead, by developing the proper back-end system, educators will be given an opportunity to import their own text using an XML file, similar to that seen in the interactive objects system currently implemented. This will allow educators to take on some responsibilities of the developers without need of their service. This can also be extended to allow educators full customizability of their own scenarios. This will be done by allowing educators to edit an XML file which will provide the game with information regarding; location of the fire, size of fire, steps needed, and what those steps are, amongst others. Using this information, new scenarios can be created by educators themselves without requiring the assistance of an expert developer.

The content of the game as it stands is also limited, with only four scenarios. Further scenarios will be developed to encompass all chemical lab fire hazards. Furthermore, the addition of another micro-game, such as the P.A.S.S micro-game, will be developed to teach WHMIS symbols training and safe chemical storage. Although much of the game as it stands deals with fire response training, fire prevention is just as important. Therefore, a separate game mode which allows users to navigate the lab, and report on any hazardous situations (i.e., a flammable chemical is left outside of the fireproof cabinets) will also be developed.

Chapter 8

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Appendices

Appendix A

Survey Material

A.1 Engagement Experiment Surveys

A.1.1 Demographic Questionnaire

iGO3D Engagement Questionnaire

SurveyMonkey

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	25
answered question	25
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	**87.0%**	**20**
No	13.0%	3
answered question		23
skipped question		2

3. Please indicate your gender:

	Response Percent	Response Count
Male	**95.7%**	**22**
Female	4.3%	1
answered question		23
skipped question		2

4. Please indicate your age range:

	Response Percent	Response Count
18-20	**52.2%**	**12**
21-23	43.5%	10
24-26	4.3%	1
27-29	0.0%	0
30-32	0.0%	0
33-35	0.0%	0
35+	0.0%	0
	answered question	**23**
	skipped question	**2**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	30.4%	7
6-9	**60.9%**	**14**
10-13	8.7%	2
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**23**
	skipped question	**2**

A.1.2 Game Experience Questionnaire

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	**26.1%**	**6**
5-10	17.4%	4
11-15	17.4%	4
16-20	8.7%	2
21-25	17.4%	4
26-30	4.3%	1
More than 30	8.7%	2
	answered question	**23**
	skipped question	**2**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**56.5%**	**13**
No	43.5%	10
	answered question	**23**
	skipped question	**2**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	0.0%	0
2	4.8%	1
3	4.8%	1
4	**57.1%**	**12**
5	28.6%	6
6	4.8%	1
7	0.0%	0
	answered question	**21**
	skipped question	**4**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**95.7%**	**22**
No	4.3%	1
	answered question	**23**
	skipped question	**2**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	4.3%	1
2	4.3%	1
3	13.0%	3
4	**26.1%**	**6**
5	21.7%	5
6	21.7%	5
7	8.7%	2
	answered question	**23**
	skipped question	**2**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**76.2%**	**16**
No	14.3%	3
I don't know	9.5%	2
	answered question	**21**
	skipped question	**4**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	0.0%	0
No	**90.5%**	**19**
I don't know	9.5%	2
	answered question	**21**
	skipped question	**4**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	4.3%	1
No	**87.0%**	**20**
I don't know	8.7%	2
	answered question	**23**
	skipped question	**2**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**79.2%**	**19**
No	20.8%	5
	answered question	**24**
	skipped question	**1**

15. If you answered “Yes”, which console(s) do you currently own (specify all)

	Response Percent	Response Count
Playstation 3	**68.4%**	**13**
Xbox 360	63.2%	12
Nintendo Wii	42.1%	8
Nintendo 3DS	10.5%	2
Other	52.6%	10
	Other (please specify)	10
	answered question	**19**
	skipped question	**6**

16. Approximately how much money have you spent in the last year on console games?

	Response Percent	Response Count
None	**26.3%**	**5**
$10-$49	0.0%	0
$50-$99	21.1%	4
$100-$199	15.8%	3
$200-$299	**26.3%**	**5**
$300-$399	0.0%	0
$400-$499	10.5%	2
$500 or more	0.0%	0
	answered question	**19**
	skipped question	**6**

17. Do you currently play games on your PC?

	Response Percent	Response Count
Yes	**95.7%**	**22**
No	4.3%	1
	answered question	**23**
	skipped question	**2**

18. Do you currently wear prescription eye glasses?

	Response Percent	Response Count
Yes	43.5%	10
No	**56.5%**	**13**
	answered question	**23**
	skipped question	**2**

19. In your traditional 2D gaming experience please indicate the importance of the following, 1=not-important, 5 being most important:

	1	2	3	4	5	Rating Average	Rating Count
Multi-Player Mode	8.7% (2)	13.0% (3)	17.4% (4)	**39.1% (9)**	21.7% (5)	3.52	23
Single Player Mode	0.0% (0)	4.3% (1)	8.7% (2)	21.7% (5)	**65.2% (15)**	4.48	23
Realistic Graphics (visuals)	4.3% (1)	8.7% (2)	**43.5% (10)**	34.8% (8)	8.7% (2)	3.35	23
Quality of Audio	0.0% (0)	0.0% (0)	**34.8% (8)**	30.4% (7)	**34.8% (8)**	4.00	23
Surround Sound Audio	0.0% (0)	13.0% (3)	**56.5% (13)**	21.7% (5)	8.7% (2)	3.26	23
Story	0.0% (0)	0.0% (0)	17.4% (4)	**52.2% (12)**	30.4% (7)	4.13	23
Interactivity	0.0% (0)	0.0% (0)	13.0% (3)	39.1% (9)	**47.8% (11)**	4.35	23
						answered question	**23**
						skipped question	**2**

20. For games in stereoscopic 3D, please indicate the importance of the following:

	1	2	3	4	5	Rating Average	Rating Count
Seeing deeply INTO the screen	4.3% (1)	0.0% (0)	30.4% (7)	**39.1% (9)**	26.1% (6)	3.83	23
Having objects come OUT of the screen	0.0% (0)	4.3% (1)	**34.8% (8)**	**34.8% (8)**	26.1% (6)	3.83	23
Not wearing glasses while playing	0.0% (0)	17.4% (4)	**43.5% (10)**	17.4% (4)	21.7% (5)	3.43	23
Playing for more than 1 hour	0.0% (0)	0.0% (0)	30.4% (7)	**43.5% (10)**	26.1% (6)	3.96	23
Realistic Graphics (visuals)	0.0% (0)	13.0% (3)	**30.4% (7)**	**30.4% (7)**	26.1% (6)	3.70	23
Multiplayer Mode	8.7% (2)	8.7% (2)	**52.2% (12)**	21.7% (5)	8.7% (2)	3.13	23
						answered question	**23**
						skipped question	**2**

21. Was the game in 3D or 2D?

		Response Percent	Response Count
3D		**65.2%**	**15**
2D		34.8%	8
		answered question	**23**
		skipped question	**2**

A.1.3 Game Engagement Questionnaire

22. Have you played this game before?

		Response Percent	Response Count
Yes		30.4%	7
No		**69.6%**	**16**
		answered question	**23**
		skipped question	**2**

23. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**69.6% (16)**	17.4% (4)	13.0% (3)	1.43	23
				answered question	**23**
				skipped question	**2**

24. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	17.4% (4)	**47.8% (11)**	34.8% (8)	2.17	23
				answered question	**23**
				skipped question	**2**

25. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	30.4% (7)	**47.8% (11)**	21.7% (5)	1.91	23
				answered question	**23**
				skipped question	**2**

26. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	4.3% (1)	**95.7% (22)**	0.0% (0)	1.96	23
				answered question	**23**
				skipped question	**2**

27. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	13.0% (3)	**52.2% (12)**	34.8% (8)	2.22	23
				answered question	**23**
				skipped question	**2**

28. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	8.7% (2)	**73.9% (17)**	17.4% (4)	2.09	23
				answered question	**23**
				skipped question	**2**

29. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	8.7% (2)	**82.6% (19)**	8.7% (2)	2.00	23
				answered question	**23**
				skipped question	**2**

30. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	21.7% (5)	**43.5% (10)**	34.8% (8)	2.13	23
				answered question	**23**
				skipped question	**2**

31. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	30.4% (7)	**47.8% (11)**	21.7% (5)	1.91	23
				answered question	**23**
				skipped question	**2**

32. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don’t answer when someone talks to me	4.3% (1)	**82.6% (19)**	13.0% (3)	2.09	23
				answered question	**23**
				skipped question	**2**

33. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can’t tell that I’m getting tired	34.8% (8)	**39.1% (9)**	26.1% (6)	1.91	23
				answered question	**23**
				skipped question	**2**

34. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**47.8% (11)**	34.8% (8)	17.4% (4)	1.70	23
				answered question	**23**
				skipped question	**2**

35. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	34.8% (8)	**43.5% (10)**	21.7% (5)	1.87	23
				answered question	**23**
				skipped question	**2**

36. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	13.0% (3)	**82.6% (19)**	4.3% (1)	1.91	23
				answered question	**23**
				skipped question	**2**

37. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**47.8% (11)**	30.4% (7)	21.7% (5)	1.74	23
				answered question	**23**
				skipped question	**2**

38. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	**56.5% (13)**	17.4% (4)	26.1% (6)	1.70	23
				answered question	**23**
				skipped question	**2**

39. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	**47.8% (11)**	39.1% (9)	13.0% (3)	1.65	23
				answered question	**23**
				skipped question	**2**

40. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**78.3% (18)**	8.7% (2)	13.0% (3)	1.35	23
				answered question	**23**
				skipped question	**2**

41. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can’t stop playing	**34.8% (8)**	**34.8% (8)**	30.4% (7)	1.96	23
				answered question	**23**
				skipped question	**2**

42. Was the game in 3D or 2D?

	Response Percent	Response Count
3D	43.5%	10
2D	**56.5%**	**13**
	answered question	**23**
	skipped question	**2**

43. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of time	**60.9% (14)**	34.8% (8)	4.3% (1)	1.43	23
				answered question	**23**
				skipped question	**2**

44. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Things seem to happen automatically	30.4% (7)	**65.2% (15)**	4.3% (1)	1.74	23
				answered question	**23**
				skipped question	**2**

45. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel different	26.1% (6)	**65.2% (15)**	8.7% (2)	1.83	23
				answered question	**23**
				skipped question	**2**

46. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel scared	0.0% (0)	**100.0% (23)**	0.0% (0)	2.00	23
				answered question	**23**
				skipped question	**2**

47. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
The game feels real	26.1% (6)	**56.5% (13)**	17.4% (4)	1.91	23
				answered question	**23**
				skipped question	**2**

48. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
If someone talks to me, I don't hear them	8.7% (2)	**73.9% (17)**	17.4% (4)	2.09	23
				answered question	**23**
				skipped question	**2**

49. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I get wound up	4.3% (1)	**82.6% (19)**	13.0% (3)	2.09	23
				answered question	**23**
				skipped question	**2**

50. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Time seems to kind of standstill or stop	39.1% (9)	**47.8% (11)**	13.0% (3)	1.74	23
				answered question	**23**
				skipped question	**2**

51. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel spaced out	26.1% (6)	**65.2% (15)**	8.7% (2)	1.83	23
				answered question	**23**
				skipped question	**2**

52. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I don't answer when someone talks to me	8.7% (2)	**73.9% (17)**	17.4% (4)	2.09	23
				answered question	**23**
				skipped question	**2**

53. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I can't tell that I'm getting tired	30.4% (7)	**52.2% (12)**	17.4% (4)	1.87	23
				answered question	**23**
				skipped question	**2**

54. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing seems automatic	**47.8% (11)**	34.8% (8)	17.4% (4)	1.70	23
				answered question	**23**
				skipped question	**2**

55. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
My thoughts go fast	**56.5% (13)**	34.8% (8)	8.7% (2)	1.52	23
				answered question	**23**
				skipped question	**2**

56. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I lose track of where I am	8.7% (2)	**87.0% (20)**	4.3% (1)	1.96	23
				answered question	**23**
				skipped question	**2**

57. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play without thinking about how to play	**60.9% (14)**	30.4% (7)	8.7% (2)	1.48	23
				answered question	**23**
				skipped question	**2**

58. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
Playing makes me feel calm	**56.5% (13)**	13.0% (3)	30.4% (7)	1.74	23
				answered question	**23**
				skipped question	**2**

59. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I play longer than I meant to	**52.2% (12)**	43.5% (10)	4.3% (1)	1.52	23
				answered question	**23**
				skipped question	**2**

60. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I really get into the game	**78.3% (18)**	8.7% (2)	13.0% (3)	1.35	23
				answered question	**23**
				skipped question	**2**

61. Answer the following as they applied to you while you were playing this game, by choosing Yes, No, or Maybe.

	Yes	No	Maybe	Rating Average	Rating Count
I feel like I just can't stop playing	**43.5% (10)**	39.1% (9)	17.4% (4)	1.74	23
				answered question	**23**
				skipped question	**2**

62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)

	Response Count
	21
answered question	**21**
skipped question	**4**

A.1.4 Free-Form Comments

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
1	Both sessions were fun, however it was much harder for me to play the 3D one of the two because my eyes were not able to focus clearly. As a result many of the things that were supposed to be appearing to "pop out of the screen" ended up appearing as two images. This also caused me to get a headache. While playing the 2D version I felt more immersed into the experience but that may be simply because I wasn't so focused on trying to see the game properly.	Nov 25, 2011 4:44 PM
2	Both looked amazing, and I enjoyed the 3D	Nov 25, 2011 4:42 PM
3	The 3D session was horrible. My eyes/head hurt most of the time when the camera was not zoomed out too much. When the camera was zoomed out (example, in the first area where all 3 characters meet) the 3D works nicely and looks great, it feels real. Overall, the 3D was not a good experience although I can imagine it being better if I didn't see two of everything. In 3D when it 'did' work right, I could not tell sometime where to jump (the foreground hid the background in such a way that I could not tell which platform to jump to and would get hurt).	Nov 24, 2011 5:07 PM
4	my eyes need to refocus. An option that allows the user to scroll how far apart the 2 layers are in order to adjust for a specific user's eyes would be a big help.	Nov 24, 2011 5:07 PM
5	The 3d version was really jarring on the 3rd level. I also didnt like that I had to sit so far away from my comfort zone in order for the 3d layers to converge. Fun game over all :D. I'd definately play more 3d games if i had a 3d monitor. I liked how some parts of the level had really extreme 3d objects. I also liked the subtle 3d objects. I think a balance between both adds to the experience. Something needs to be done to make it easier to focus though,	Nov 24, 2011 5:07 PM
6	Although a lot of the scene looked great in the 3D, the entire foreground was ruined. The game not only lost it's apeal it became much harder to play.	Nov 24, 2011 5:06 PM
7	3D takes a little getting used to, but once you get used to it it is pretty cool. I wouldn't say either was more fun than the other, it's just a different way to experience the game.	Nov 24, 2011 5:06 PM
8	3d was more fun, both were playing a bad game. Initial batch of questions need to be re-orderd/ worded	Nov 24, 2011 5:05 PM
9	2D somehow felt faster, as in framerate. 3D felt kind of odd, there was doubling in some areas. I noticed immedeately the switch to 2D from 3D	Nov 18, 2011 4:33 PM
10	noticed the 3D almost right away with the foreground and background affects. A little blurry around some edges and a slight headache at times. Game still felt the same control wise, but the visual stood out.	Nov 17, 2011 4:40 PM
11	I felt the first session was more fun because the graphics felt more live and realatilc. Everything in the game seen to pop out at you and the background is amazning.	Nov 17, 2011 4:40 PM
12	3D hurt my eyes, both were fun. 3D was interesting but it was really hard to concentrate on the screen without my eyes hurting. I'm not sure if the monitor was too close or I was just at a bad angle to play the game in 3D. But sometimes I would get double vision and see the 3D as if I didnt have glasses. Thats what	Nov 15, 2011 4:56 PM

Page 47, Q62. Please comment or compare your two sessions? (Which one was more fun, any other remarks)		
	hurt my eyes when it didn't seem to focus properly.	
13	Both of them were equally fun. It just that the second time I played it, I knew more about the game controls and the beginning levels than the first play, so I was able to play with more speed.	Nov 15, 2011 4:55 PM
14	The 2nd time around was more fun for me. However I feel like the 3D didn't always register like I was sometimes seeing double images. Thanks	Nov 15, 2011 4:54 PM
15	The only main differwence between the 2 is that the 3d one at time was hard to see due to the fact that it wouldnt be in 3d but 2 different player images then it focuses into 3d and back out.... only noticed when the camera was zooming in or was zoomed in already. Enjoyed the working 3d graphics more then the 2d	Nov 14, 2011 5:17 PM
16	Session 2 started out painful on the eyes until I adjusted to the 3D, then it looked really cool	Nov 14, 2011 5:16 PM
17	The 3d was defenelty more fun. Got me into playing longer. the effects are much better on 3d	Nov 14, 2011 5:16 PM
18	3d was more engaging, though certain parts of the level (tree branches and stuff in the foreground) stuck out like a sore thumb and kind of distracted me from the rest of the game.	Nov 14, 2011 5:16 PM
19	3D was definitely better. The feel of depth made a huge difference. If I had a 3D tv I would invest in 3D games.	Nov 14, 2011 5:16 PM
20	3D was definetely more enjoyable and engaging, however the calibration for my eyes didn't seem quite right. So it enhanced the experience while making some parts of the experience less enjoyable since it would look too blurred.	Nov 14, 2011 5:16 PM
21	I thought the 3D was more fun but I was so immersed I missed some important pop ups such as when the characters leveled up.	Nov 14, 2011 5:15 PM

A.2 Calibration Experiment Surveys

A.2.1 Demographic Questionnaire

Interactive Stereoscopic Calibration Demographic Questionnaire

SurveyMonkey

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	22
answered question	22
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	**77.3%**	**17**
No	22.7%	5
answered question		**22**
skipped question		**0**

3. Please indicate your gender:

	Response Percent	Response Count
Male	**90.9%**	**20**
Female	9.1%	2
answered question		**22**
skipped question		**0**

4. Please indicate your age range:

	Response Percent	Response Count
18-20	**59.1%**	**13**
21-23	27.3%	6
24-26	13.6%	3
27-29	0.0%	0
30-32	0.0%	0
33-35	0.0%	0
35+	0.0%	0
	answered question	**22**
	skipped question	**0**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	36.4%	8
6-9	**45.5%**	**10**
10-13	18.2%	4
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**22**
	skipped question	**0**

A.2.2 Game Experience Questionnaire

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	22.7%	5
5-10	**36.4%**	**8**
11-15	22.7%	5
16-20	9.1%	2
21-25	9.1%	2
26-30	0.0%	0
More than 30	0.0%	0
	answered question	**22**
	skipped question	**0**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**63.6%**	**14**
No	36.4%	8
	answered question	**22**
	skipped question	**0**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	5.6%	1
2	16.7%	3
3	**27.8%**	**5**
4	22.2%	4
5	16.7%	3
6	11.1%	2
7	0.0%	0
	answered question	**18**
	skipped question	**4**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**95.5%**	**21**
No	4.5%	1
	answered question	**22**
	skipped question	**0**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	9.5%	2
2	4.8%	1
3	19.0%	4
4	9.5%	2
5	**42.9%**	**9**
6	14.3%	3
7	0.0%	0
	answered question	**21**
	skipped question	**1**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**76.2%**	**16**
No	19.0%	4
I don't know	4.8%	1
	answered question	**21**
	skipped question	**1**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	9.5%	2
No	**90.5%**	**19**
I don't know	0.0%	0
	answered question	**21**
	skipped question	**1**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	0.0%	0
No	**100.0%**	**22**
I don't know	0.0%	0
	answered question	**22**
	skipped question	**0**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**90.9%**	**20**
No	9.1%	2
	answered question	**22**
	skipped question	**0**

15. If you answered “Yes”, which console(s) do you currently own (specify all)

	Response Percent	Response Count
Playstation 3	**60.0%**	**12**
Xbox 360	55.0%	11
Nintendo Wii	45.0%	9
Nintendo 3DS	30.0%	6
Other	40.0%	8
	Other (please specify)	8
	answered question	**20**
	skipped question	**2**

16. Approximately how much money have you spent in the last year on console games?

	Response Percent	Response Count
None	20.0%	4
$10-$49	5.0%	1
$50-$99	15.0%	3
$100-$199	20.0%	4
$200-$299	**25.0%**	**5**
$300-$399	15.0%	3
$400-$499	0.0%	0
$500 or more	0.0%	0
	answered question	**20**
	skipped question	**2**

17. Do you currently play games on your PC?

	Response Percent	Response Count
Yes	**86.4%**	**19**
No	13.6%	3
	answered question	**22**
	skipped question	**0**

18. Do you currently wear prescription eye glasses?

	Response Percent	Response Count
Yes	31.8%	7
No	**68.2%**	**15**
	answered question	**22**
	skipped question	**0**

19. In your traditional 2D gaming experience please indicate the importance of the following, 1=not-important, 5 being most important:

	1	2	3	4	5	Rating Average	Rating Count
Multi-Player Mode	4.5% (1)	18.2% (4)	**27.3% (6)**	22.7% (5)	**27.3% (6)**	3.50	22
Single Player Mode	4.5% (1)	9.1% (2)	13.6% (3)	18.2% (4)	**54.5% (12)**	4.09	22
Realistic Graphics (visuals)	13.6% (3)	22.7% (5)	**36.4% (8)**	13.6% (3)	13.6% (3)	2.91	22
Quality of Audio	0.0% (0)	4.5% (1)	**40.9% (9)**	22.7% (5)	31.8% (7)	3.82	22
Surround Sound Audio	13.6% (3)	**27.3% (6)**	22.7% (5)	13.6% (3)	22.7% (5)	3.05	22
Story	4.5% (1)	9.1% (2)	27.3% (6)	**31.8% (7)**	27.3% (6)	3.68	22
Interactivity	0.0% (0)	0.0% (0)	9.1% (2)	36.4% (8)	**54.5% (12)**	4.45	22
						answered question	**22**
						skipped question	**0**

20. For games in stereoscopic 3D, please indicate the importance of the following:

	1	2	3	4	5	Rating Average	Rating Count
Seeing deeply INTO the screen	0.0% (0)	14.3% (3)	14.3% (3)	33.3% (7)	**38.1% (8)**	3.95	21
Having objects come OUT of the screen	0.0% (0)	23.8% (5)	4.8% (1)	33.3% (7)	**38.1% (8)**	3.86	21
Not wearing glasses while playing	0.0% (0)	**28.6% (6)**	23.8% (5)	19.0% (4)	**28.6% (6)**	3.48	21
Playing for more than 1 hour	9.5% (2)	19.0% (4)	**33.3% (7)**	19.0% (4)	19.0% (4)	3.19	21
Realistic Graphics (visuals)	9.5% (2)	14.3% (3)	28.6% (6)	**33.3% (7)**	14.3% (3)	3.29	21
Multiplayer Mode	15.0% (3)	25.0% (5)	**35.0% (7)**	5.0% (1)	20.0% (4)	2.90	20
						answered question	**21**
						skipped question	**1**

A.2.3 Free-Form Comments

Page 4, Q21. Please feel free to leave any comments about the experiment? (Likes, dislikes, things you felt were important, things you would have changed, etc.)		
1	I saw red stripes randomly, across the screen horizontaly. I also found it difficult to get the game into focus at the start. On the second demo, the first time around, I misunderstood the message to press enter, and pressed it before adjusting the slider, it was however where I felt comfortable anyways.	Sep 19, 2012 3:44 PM
2	When I had to move the slider to change the intensity, I was always able to focus on the character but I was seeing double of the buildings to the left and right of the screen. The setting I chose was the setting that was the least double vision to me, but there was still some duplication.	Sep 19, 2012 3:10 PM
3	when edjusting the stereoscopy of the game. it was more effective when its on least stereoscopy. also the stereoscopic view gave me headaches after 5 minutes of playing.	Sep 19, 2012 2:57 PM
4	I liked the simplicity of the experiment. I did not enjoy how the experiment was very repetitive and that if there was more to the experiment such as better scenery it would be better.	Sep 19, 2012 2:44 PM
5	I performed better in the second test than the first.	Sep 19, 2012 2:31 PM
6	Feels like the 3D beyond the smallest part of the slider doesn't work.	Sep 19, 2012 2:14 PM
7	Nothing really of note.	Sep 19, 2012 2:05 PM
8	There were red lines all over the screen.	Sep 19, 2012 1:55 PM
9	It's really hard to find the right angle to view the game and sometimes it feels like I have to cross my eyes and it hurts a little.	Sep 19, 2012 10:59 AM
10	The game itself didn't seem to be a good example of 3d gameplay, maybe altering it so that their are sublt eparticle effects that are 3d, or things coming closer to the screen (such as projectiles or characters). Pause feature would be useful, just to be able to stop in midjump to analyze how close things appeared. A Model view mode, to look at the rest of the level would be nice, but I do understand it may not me practical. all in all, the experiment may benefit from a more polished game.	Aug 15, 2012 2:36 PM
11	couldnt get the full 3d to work. I could see the depth but the images were ghosting a lot, so it led to me avoiding the 3d version.	Aug 15, 2012 2:18 PM
12	During the first set of tests, I think I was outside of the 3D sweet spot for the monitor. I also feel like choosing the left or right screen can lead a person to only focus on that side of the screen. Similarly, I found myself trying "average" and "extreme" 3d using the slider test and then looking for the best "fit" between the two.	Aug 15, 2012 9:55 AM
13	For the first run of the game I think I accidently selected the screen I didn't like a few times, but the second time I was definatly more accurate	Aug 14, 2012 12:09 PM
14	I like the hat.	Aug 14, 2012 11:37 AM

A.3 Spatial Learning Surveys

A.3.1 Demographic Questionnaire

User Performance in a Fire Training Game

1. Interviewee ID (Ask the interviewing supervisor to fill this out)

	Response Count
	34
answered question	34
skipped question	0

2. Are you a Game Development & Entrepreneurship student at UOIT

	Response Percent	Response Count
Yes	**76.5%**	**26**
No	23.5%	8
answered question		34
skipped question		0

3. Please indicate your gender:

	Response Percent	Response Count
Male	**91.2%**	**31**
Female	8.8%	3
answered question		34
skipped question		0

A.3.2 Game Experience Questionnaire

4. Please indicate your age range:

	Response Percent	Response Count
18-20	39.4%	13
21-23	**51.5%**	**17**
24-26	6.1%	2
27-29	3.0%	1
30-32	0.0%	0
33-35	0.0%	0
35+	0.0%	0
	answered question	**33**
	skipped question	**1**

5. At what age did you start playing video games?

	Response Percent	Response Count
2-5	32.4%	11
6-9	**47.1%**	**16**
10-13	20.6%	7
14-17	0.0%	0
18-21	0.0%	0
22-25	0.0%	0
26+	0.0%	0
	answered question	**34**
	skipped question	**0**

6. Approximately how many hours per week do you play video games?

	Response Percent	Response Count
Less than 5	**32.4%**	**11**
5-10	26.5%	9
11-15	23.5%	8
16-20	8.8%	3
21-25	5.9%	2
26-30	0.0%	0
More than 30	2.9%	1
	answered question	**34**
	skipped question	**0**

7. Have you ever played a game in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**55.9%**	**19**
No	44.1%	15
	answered question	**34**
	skipped question	**0**

8. For video games, how would you rate the stereoscopic 3D experience (vs traditional 2D games) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	8.8%	3
2	8.8%	3
3	**29.4%**	**10**
4	**29.4%**	**10**
5	20.6%	7
6	2.9%	1
7	0.0%	0
	answered question	**34**
	skipped question	**0**

9. Have you ever seen a movie in stereoscopic 3D before?

	Response Percent	Response Count
Yes	**100.0%**	**33**
No	0.0%	0
	answered question	**33**
	skipped question	**1**

10. In the movie theatre, how would you rate the stereoscopic 3D experience (vs traditional 2D movies) (1 = 2D is much more enjoyable, 4 = equally enjoyable, 7 = stereoscopic 3D is much more enjoyable)

	Response Percent	Response Count
1	12.1%	4
2	15.2%	5
3	9.1%	3
4	**36.4%**	**12**
5	24.2%	8
6	3.0%	1
7	0.0%	0
	answered question	**33**
	skipped question	**1**

11. Do you currently own a HDTV

	Response Percent	Response Count
Yes	**78.8%**	**26**
No	18.2%	6
I don't know	3.0%	1
	answered question	**33**
	skipped question	**1**

12. Do you currently own a 3D capable HDTV

	Response Percent	Response Count
Yes	11.8%	4
No	**79.4%**	**27**
I don't know	8.8%	3
	answered question	**34**
	skipped question	**0**

13. Do you currently own a 3D capable PC Monitor

	Response Percent	Response Count
Yes	2.9%	1
No	**88.2%**	**30**
I don't know	8.8%	3
	answered question	**34**
	skipped question	**0**

14. Do you currently own a gaming console

	Response Percent	Response Count
Yes	**82.4%**	**28**
No	17.6%	6
	answered question	**34**
	skipped question	**0**

A.3.3 Free-Form Comments

Day 1

Page 6, Q22. Please comment about the experiment.		
1	Was a fun experiment; would have been nice to have instructions on what the optimal distance is to stay away from the fire.	Mar 7, 2013 3:02 PM
2	The minimum distance felt a little strange, but that is understandable. The 3D did not help, I used the size of the object and its relation to the textures on the ground to judge distance.	Mar 7, 2013 2:56 PM
3	the experiment gave me awareness on how far i should be in using the erxtinguisher. usually i use an extinguisher/any spraying items point blank.	Mar 7, 2013 2:38 PM
4	The 3D effect was not very strong.	Mar 7, 2013 2:12 PM
5	I always felt the need to be cautious and stay at far from the fire as possible; I never had a flashing red screen because I was afraid to get too close.	Mar 6, 2013 12:30 PM
6	Aiming of the firehydrant seemed a little clunky, and there was a possibility for the fire to spawn on top of the player. The spatial sweet spot seemed pretty easy to learn.	Mar 6, 2013 12:21 PM
7	- Fire spawned on me, which made it a tad more difficult - Text warnings were in the way and made it hard to measure distance at first	Mar 6, 2013 11:42 AM
8	The 2nd yellow prompt should be fixed to dislpay the correct message	Mar 6, 2013 10:03 AM
9	game was more like 2.5D not quite defined dimentions. i can see the depth of the liquid that you spray the fire. depth need to be more defined to call that 3D. got a hang of the game fast and the distance relitivly well.	Mar 6, 2013 9:52 AM
10	Was lots of fun and the graphics were real and enjoyable!	Feb 28, 2013 1:48 PM
11	I found the experiment to be quite accurate in relation to the distance of the fire. In the case that you were to close you would get burned and the case where if you were to far you could not put out the fire. I found the movement of the player to be rather slow but besides that the basic play of the game was standard.	Feb 28, 2013 11:32 AM
12	I never receieved a flashing red screen, and it was very easy to figure out the appropriate distance to stay from the fire.	Feb 28, 2013 11:18 AM
13	I feel safer.	Feb 27, 2013 3:34 PM
14	The movement controls were fluid and responsive and the controls of the first person view perspective with the right analog stick were very smooth, response, moved at just the right speed and it felt like the control of it was right at the palm of my hand. I give praise to the first-perspective camera aiming control because I've never been too comfortable with first-person perspective games because I felt that they lacked some of the benefits this simulation had, and I'm talking about AAA types of games. As for the gameplay mechanics, it seems that the correct distance from yourself to the fire is about 2 paces, it's just the right distance to extinguish without wasting too much retardant. I kept making the error of staying at too far a distance, which probably wasted too much retardant, this leads to believe the game was designed this way to properly judge the distance.	Feb 27, 2013 3:17 PM
15	At first I was not sure if I could move or not and I tried pressing random buttons	Feb 25, 2013 3:12 PM

Page 6, Q22. Please comment about the experiment.		
	to see if I could move. I found out later that I could not move. So I guess that part is a little unclear	
16	It was fun	Feb 25, 2013 3:05 PM
17	took too long to put out fires, wall/floor pattern repetitive and annoying.	Feb 25, 2013 2:03 PM
18	easy to learn	Feb 25, 2013 1:22 PM
19	it was a realistic experience in terms of deals with fire, except for the fac that the fire did not spread around.	Feb 25, 2013 12:43 PM
20	It helpped with my spacial senses and i was able to see how far away i was from the fire in 3-space	Feb 25, 2013 12:29 PM
21	My eyes hurt.	Feb 25, 2013 12:11 PM
22	I think it will be a good teaching tool about fire safety with a bit more polishing.	Feb 25, 2013 11:44 AM
23	Learning experience was good. Recieve a good understand of the appropriate distance needed to put out a fire safetly	Feb 25, 2013 10:36 AM
24	Kept turning right. The next fire was usually on my left. Not sure if this was just habit. Also wasn't sure of the impact of 3D. The main indicator I used to measure distance was the size of objects on the screen, which would be the same in 2D. (I think).	Feb 21, 2013 1:38 PM
25	when told that i was too close to fire, the sign blocked the fire and made it hard to judge distance	Feb 20, 2013 11:34 AM
26	sometimes the fire appeared randomly right beside me and I didn't have control of being to close to the fire at that point. At the beginning of the game I was confused because I did not know that I couldn't move closer to the fire. A explanation about the controller and what each key will be used for will be helpful.	Feb 20, 2013 10:57 AM

Day 2

Page 6, Q4. Please comment about the experiment.		
1	the experimwent thought me the proper distance alloted in extringuishing the fire. the experiment from the day before was engraved in my head that it was applied to today's experiment	Mar 8, 2013 10:57 AM
2	Didn't feel as if I learned what the correct distance was to stay away from fires.	Mar 8, 2013 10:48 AM
3	why was I so slow	Mar 8, 2013 10:40 AM
4	Hope you find out what you want.	Mar 8, 2013 8:59 AM
5	Though this was in 3D, I could sometimes see blue edges on objects.	Mar 7, 2013 1:55 PM
6	remembered the testing day alittle but once i started to play the game then it started to come back to me.	Mar 7, 2013 1:02 PM
7	Turn speed was a little low, liked how you had to plan your route to avoid the fire to get the extinguisher.	Mar 7, 2013 10:13 AM
8	Pretty sure I got a question wrong. Also I want to be able to run because I am impatient and most FPS games these days let you run.	Mar 1, 2013 10:13 AM
9	Well done, had a lot of fun! thanks!	Mar 1, 2013 9:55 AM
10	Like before, the experiemnt is quite accurate in relation to the fire and distance away. The 3D was not apparent for both trials though in the first experiment it seemed as though it were. The only problem still, which isn't actually a problem, is the movement which could be adjusted slightly so the rotation is faster.	Mar 1, 2013 9:35 AM
11	Enjoyable	Mar 1, 2013 9:15 AM
12	I feel even safer.	Feb 28, 2013 11:43 AM
13	While the 3D doesn't come out of the screen which I don't think it's supposed to anyway, it certainly has depth. Though the 3D at the beginning of the on screen instructions is very eye straining at first.	Feb 28, 2013 11:08 AM
14	The second time my eyes and brain started to hurt a little and everything looked a little different	Feb 26, 2013 1:21 PM
15	I think this has the potential to be a good teaching tool about fire safety.	Feb 26, 2013 11:56 AM
16	it felt a bit laggy	Feb 26, 2013 11:46 AM
17	Sensitivity too low.	Feb 26, 2013 10:48 AM
18	Side Note experiment will be played twice not put out the fire twice	Feb 26, 2013 10:39 AM
19	This was easier for me to concieve the direction i was going, and my position in 3-space, than it would have been in a standard first person game	Feb 26, 2013 9:47 AM
20	slow moving need sprint button	Feb 26, 2013 9:32 AM
21	easy to learn	Feb 26, 2013 8:56 AM

Page 6, Q4. Please comment about the experiment.		
22	easier to control with no messages on the screen.	Feb 22, 2013 2:17 PM
23	Note: I'm not sure how strong my 3D attenuity is. but, I find 3d to be not as good as 2d. 3D might be effective on a larger scale, where the monitor stretched further than a person's field of view (like an omnimax or a planetarium). Without that, the render is still bound to the screen, so most of the 3D effect is lost.	Feb 22, 2013 2:05 PM
24	it was awesome!	Feb 21, 2013 10:02 AM

Appendix B

Experiment Data

Dependent Variable	Group	test	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Average Distance	2D-2D	post-test	9.242	.341	8.569	9.915
		pretest	8.993	.341	8.320	9.666
		retention	8.123	.341	7.451	8.796
	2D-3D	post-test	9.242	.341	8.569	9.915
		pretest	8.993	.341	8.320	9.666
		retention	7.722	.341	7.049	8.394
	3D-2D	post-test	9.549	.341	8.877	10.222
		pretest	9.972	.341	9.299	10.645
		retention	7.491	.341	6.818	8.164
	3D-3D	post-test	9.549	.341	8.877	10.222
		pretest	9.972	.341	9.299	10.645
		retention	7.859	.341	7.186	8.531

Figure B.1: Experimental results. Average distance amongst each group that was analysed with standard deviation.

Dependent Variable		(I) Group	(J) Group	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Average Distance	Tukey HSD	2D-2D	2D-3D	.963	-.588247910	.856153608
			3D-2D	.861	-.940412068	.503989449
			3D-3D	.612	-1.062951989	.381449529
		2D-3D	2D-2D	.963	-.856153608	.588247910
			3D-2D	.586	-1.074364918	.370036600
			3D-3D	.324	-1.196904838	.247496679
		3D-2D	2D-2D	.861	-.503989449	.940412068
			2D-3D	.586	-.370036600	1.074364918
			3D-3D	.971	-.844740679	.599660838
		3D-3D	2D-2D	.612	-.381449529	1.062951989
			2D-3D	.324	-.247496679	1.196904838
			3D-2D	.971	-.599660838	.844740679

Figure B.2: Multiple comparisons between groups show no significant differences with regards to distance.

Dependent Variable	Group	test	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Accuracy	2D-2D	post-test	.647	.028	.593	.701
		pretest	.575	.028	.521	.630
		retention	.667	.028	.612	.721
	2D-3D	post-test	.647	.028	.593	.701
		pretest	.575	.028	.521	.630
		retention	.655	.028	.601	.710
	3D-2D	post-test	.620	.028	.565	.674
		pretest	.602	.028	.547	.656
		retention	.659	.028	.605	.713
	3D-3D	post-test	.620	.028	.565	.674
		pretest	.602	.028	.547	.656
		retention	.638	.028	.584	.692

Figure B.3: Experimental results. Accuracy improvements after training for every group that was analysed with standard deviations.

Multiple Comparisons

Dependent Variable		(I) Group	(J) Group	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Accuracy	Tukey HSD	2D-2D	2D-3D	.998	-.0545710405	.0621107713
			3D-2D	.999	-.0554689515	.0612128603
			3D-3D	.971	-.0484395680	.0682422438
		2D-3D	2D-2D	.998	-.0621107713	.0545710405
			3D-2D	1.000	-.0592388170	.0574429949
			3D-3D	.993	-.0522094334	.0644723784
		3D-2D	2D-2D	.999	-.0612128603	.0554689515
			2D-3D	1.000	-.0574429949	.0592388170
			3D-3D	.989	-.0513115224	.0653702895
		3D-3D	2D-2D	.971	-.0682422438	.0484395680
			2D-3D	.993	-.0644723784	.0522094334
			3D-2D	.989	-.0653702895	.0513115224
	LSD	2D-2D	2D-3D	.867	-.0406054828	.0481452136
			3D-2D	.898	-.0415033938	.0472473025
			3D-3D	.660	-.0344740103	.0542766861
		2D-3D	2D-2D	.867	-.0481452136	.0406054828
			3D-2D	.968	-.0452732592	.0434774371
			3D-3D	.785	-.0382438757	.0505068207
		3D-2D	2D-2D	.898	-.0472473025	.0415033938
			2D-3D	.968	-.0434774371	.0452732592
			3D-3D	.755	-.0373459646	.0514047317
		3D-3D	2D-2D	.660	-.0542766861	.0344740103
			2D-3D	.785	-.0505068207	.0382438757
			3D-2D	.755	-.0514047317	.0373459646

Based on observed means.
The error term is Mean Square(Error) = .011.

Figure B.4: Multiple comparisons between groups show no significant differences with regards to accuracies.