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A Study of Applications of 3D Animation for Emergency Medicine Pedagogy

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A STUDY OF APPLICATIONS OF 3D ANIMATION FOR EMERGENCY MEDICINE PEDAGOGY

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For my parents

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ABSTRACT

Zheng, Huilong. M.S., Purdue University, August 2016. A Study of Applications of 3D Animation for Emergency Medicine Pedagogy. Major Professor: Nicoletta Adamo-Villani.

There is ample precedent for the use of 3D animation in education, though little research on specific applications in the field of medicine. An experiment was carried out to assess the suitability of 3D animation for educational purposes in emergency medicine courses. Two groups of experimental participants were assessed on their ability to respond to three emergency medical situations in simulated test scenarios. Both groups received equivalent information on how to treat the three different medical emergencies. The control group received the information in traditional lecture format. The experimental group instead received the information from a set of 3D animations. Participants were assessed according to the speed and accuracy with which they administered proper treatment as well as their ability to complete every step of treatment and to execute these steps in the correct order. The 3D animation and lecture groups were not generally found to score differently from a statistical perspective. Possible causes are provided.

CHAPTER 1. EXPERIMENTAL BACKGROUND

1.1 Introduction

The use of 3D animation for educational purposes is not new. Past research has found varying levels of efficacy for educational animation in terms of its ability to enhance student comprehension in the classroom. However, the application of 3D animation in medical education has not been well studied despite readily apparent qualities of 3D animation which might render it especially suited for this use. 3D animation allows simulation not just of external bodily features, but also of the inside of human bodies. 3D animation surpasses the capabilities of "real" video (including methods for obtaining video inside the body: endoscopy, etc.) insofar as it allows classroom instructors to rapidly and easily display the features of complex bodily systems as well as the relationships between these systems. This paper presents an experimental study designed to illuminate the potentials of 3D animation in medical education in contrast to a lecture-based approach (defined in Chapter 3 as "traditional education.")

In this chapter, background information for this study, including the research question, the statement of the problem and the scope of the research, is given. In addition, assumptions, limitations, and delimitations of the study are presented in this chapter.

1.2 Statement of the Problem

Education systems have historically developed to accommodate the ever-shifting array of topics that students need to learn. Change and evolution in practical teaching tools have coincided with the development of these education systems. 3D animation is one such tool that has attracted the attention of both teachers and pedagogical researchers in recent years as advancements in computer hardware and 3D technology have made these tools more accessible. Not all of this attention has been positive - dissenting opinions regarding the efficacy of 3D animation have appeared virtually since these tools started to become available (Owens, 2002). Other researchers have argued the limitations of 3D animation in certain pedagogical situations (Mayer, 2002).

For healthcare students, learning the spatial characteristics and interconnections of human body structures is as essential a task as learning the biological concepts that describe how these systems work. Traditionally, three main teaching tools have been used to help students study these structures. First are textbooks, which provide students with theoretical knowledge in the form of text, but can offer only 2D pictures and diagrams to illustrate the spatial qualities of body structures. Second are medical models, which vary greatly in their teaching potential. Even complex models which can be taken apart, reassembled, interfaced with other models, and so on can lack sufficient detail to give a complete understanding of the structure they represent. Third are cadavers, which illustrate human body structures well precisely because they are real human bodies. However, cadaver availability is limited. Medical students typically cannot access cadavers without the permission of the college or a supervising professor, while they can readily obtain textbooks and models. The goal of adopting 3D animation technology for medical education thus represents an opportunity to make the teaching strengths of cadavers more readily available to medical students.

This study's educational examples are drawn from the field of emergency medicine rather than from emergent topics in medical research for the following reasons: first, medical research practices can be so complex that it can take years to develop a complete understanding of a newly-discovered body structure. Second, the creator of the animation used in this study wishes that this animation will be widely used in the future, rather than becoming obsolete after the study. Additionally, emergency care is an area of medical science not taught only in medical schools – non-medical professionals frequently learn basic emergency procedures such as CPR, Heimlich maneuver, etc. through educational programs that include discussion of the structure of the body systems involved. Thus, choosing to examine topics in emergency medicine allowed us to consider broader implications for 3D animation in medical education.

Many studies have focused on the effects of animation in education, but few of these have provided formal evaluations of the efficacy of educational 3D animations for healthcare students. This study, which assesses the performance of an experimental and control group pre-test and post-test, is designed to determine whether animation improves student performance.

1.3 Scope

3D animation technology has been used for pedagogical purposes in a wide variety of educational programs, including medical school programs. 3D animations teaching emergency medical topics can be found outside of medical schools (for instance, on popular video streaming sites), but not all of these exhibit the complexity and systematic organization necessary for healthcare pedagogy. In addition, of the available research on the influence of 3D animation on student learning, no study has taken as its focus the teaching effectiveness of 3D animation in emergency medical care. To fill this gap in the research literature, this study aims to design a 3D animation to replace the instructor in an emergency medicine class. In this role, its goal will be teaching healthcare students treatments for several specific medical emergencies. Once designed, this study will test the effectiveness of this new form of education through comparison of student performance on pre- and post- tests.

A tremendous variety of emergency situations are typically covered in emergency medical curricula. Considering this broad range of possibilities, three situations were selected for this 3D animation: choking, drowning and lower bone fracture. These particular emergencies were chosen because their treatments require relatively little time to administer and are neither too difficult to teach in a single classroom nor so simple that they might be guessed by individuals with no medical training. These specific qualities put these emergencies in a "goldilocks" zone of suitability for teaching via 3D animation.

1.4 Significance

This study's significance lies in its exploration of the influence of educational 3D animation on healthcare student learning. However, because the emergency medicine topics examined in this study are also sometimes taught to non-medical professionals, the design and creation of this 3D animation bear relevance not just for healthcare students and their instructors, but also for people without any medical background.

Additionally, the evaluation of student performance via a pre-test and post-test in this research provides a standardized method of evaluation for technology-assisted medical education. Thus, in addition to investigating a tool that might aid student learning in the future, this study also provides a way for future researchers to further investigate specific topics relating to the use of 3D animation in pedagogy.

1.5 Definition of Key Terms

Animation – "A series of images played in fast succession so that, to the human eye, the outcome is apparently in motio" (Park & Gittelman, 1992).

Medical emergency – "An acute injury or illness that causes an immediate and sudden risk to a normal person's life or long term health" (Caroline, 1981).

Choking – **"**The mechanical obstruction of the flow of air from the environment into the lungs" (Ross & Chan, 2006).

Drowning – "Respiratory impairment from being in or under a liquid" (Beeck & Branche, 2005).

Bone fracture – "A medical condition in which there is damage in the continuity of a bone" (Sabiston & Townsend, 2008).

1.6 Research Question

Previous studies have assessed whether animation technology is able to improve students' ability to visualize various bodily systems and structures. 3D animation technology is notable for its potential to assist healthcare students in visualizing the spatial features and interconnections of complex inner structures of the human body. However, the application of 3D animation in emergency medicine education remains unexplored. Thus, this study aims to determine whether a 3D animation can improve healthcare students' comprehension of a lesson comprised of several topics in emergency medicine. In addition to this primary research question, several other secondary questions will be addressed by examining the experimental data produced in the study. These are: "Does gender have an effect on students' perceptions of the educational efficacy of 3D animation?" and "Will students prefer 3D animation learning to traditional lecture-based education after being taught by 3D animation?"

1.7 Assumptions

The assumptions inherent to this study, which derive both from human and environmental factors, include:

- The participants in the study are assumed to lack fundamental misunderstandings of common testing protocol which might skew their results on the tests. In order to prevent such misunderstandings, the participants are encouraged to ask for clarification if the test instructions or any question on the test causes confusion.
- The participants are assumed to give their best effort toward the tasks they are presented with. They are assumed to pay full attention during the emergency medicine lesson and to focus on getting the best possible score on the tests administered before and after it.
- Each participant is assumed to take part in the study without outside help. Participants are instructed to finish both tests by themselves without any aid other than the lecture or 3D animation.

1.8 Limitations

The limitations inherent to this study include the following:

- Only new healthcare students are used in this study. This means that the participants should lack a detailed scientific understanding of the medical emergencies presented in the study.
- Only three types of medical emergency are covered in the lesson and tests: choking, drowning and bone fracture. The specific focus of the latter emergency is mainly confined to fractures of the lower leg.
- The study aims to only assess the students' understanding of the topics presented as well as their performance on a timed test covering these topics. It is not intended to assess overall intelligence, academic ability, or other factors.

1.9 Delimitations

The delimitations of this study include the following:

- Students from majors like Engineering and Computer Science are not tested in this study, despite the fact that their majors are sometimes related to study of emergency medicine.
- Medical emergencies other than the three mentioned above are not tested in this study.
- Factors relating to students' studying efficiency are not considered in this study.

1.10 Summary

The medical students acting as subjects in this study take a pre-test before watching a 3D animation or receiving an in-person lecture. Both cover the same material relating to the three medical emergencies mentioned above. After the animation/lecture, the subjects take a post-test. The results of the pre-test and post-test are used to assess the improvement of the subjects' understanding of the material as well as to compare the scores of those who watch the 3D animation and those who receive a lecture.

This chapter discusses the background of the study, including a statement of the problem, the scope of the research, and the specific research questions the study seeks to answer. To minimize misunderstanding, the experimental assumptions, limitations and delimitations of the study are clarified.

CHAPTER 2. REVIEW OF LITERATURE

2.1 Introduction

Based on this project's research question, three topics lend themselves to exploration through research: medical emergencies, 3D animation and visualization technology, and applications of technology in medicine. While there are a wide variety of medical emergencies frequently taught to students of emergency medicine, not all of these are suitable for translation into 3D animations as required by in study. For this reason, the three emergencies chosen for this study (which, to reiterate, are drowning, choking and lower bone fracture) are emergencies which might reasonably lend themselves to teaching via examination of internal body structures using 3D animation.

The first part of this chapter explores extant research on these three medical emergencies and details best practices for treating them in pre-hospital situations. The second part of this chapter discusses the current state of 3D animation technology and its visualization applications in medical pedagogy. Best practices for observation of human bodies in 3D environments and methods of translating data from 2D visualizations into 3D models to allow for observation of human body structures from different angles and distances are discussed. The final part of this chapter mainly discusses previous studies of 3D animation being used in educational capacities and explores several important limitations of the technology in this role. The teaching effectiveness of animations compared to lectures given by a teacher are explored, as are the results of studies that compare animations to lectures for topics other than medical emergencies. These topics are explored with the aim of clarifying the potential advantages and disadvantages of animation-based education compared to traditional lecture-based education.

2.2 Medical Emergencies

In this section, different varieties of medical emergencies are discussed. Among these medical emergencies, the specific examples of choking, drowning, and lower bone fracture, which form the basis for this study, are examined separately.

A prospective observational study conducted at a university-affiliated tertiary referral hospital between July 2008 and December 2009 examined the role that time of response plays in emergency medical situations (Boniatti et al., 2014). Of the 1481 emergency calls corresponding to 1148 patients, 246 (21.4%) of the patients experienced delays in receiving care from an emergency medical team. Among the 246 delayed calls, physicians had a greater prevalence of delayed medical emergency team calls than timely medical emergency team calls (267 of 902 [29.6%]; $p<0.001$). Additionally, mortality was higher among patients with delayed medical emergency team activation (152 [61.8%]) at 30 days after medical emergency team review than among patients receiving timely medical emergency team activation (378 [41.9%]; $p<0.001$). In other analyses, delayed medical emergency team calls remained significantly associated with higher mortality.

The Boniatti et al. study demonstrates that delayed medical emergency team calls are common and are independently associated with higher mortality. This result reaffirms the urgent need for rapid response systems (Crit Care Med 2014; 42:26–30).

2.2.1 Drowning

According to the new definition adopted by the World Health Organization (WHO) in 2002, “Drowning is the process of experiencing respiratory impairment from submersion/immersion in liquid.” Also according to the WHO, 0.7% of all deaths around the world (more than 500,000 deaths each year), are because of unintentional drowning. However, this count may be low: “Since some cases of fatal drowning are not classified as such according to the codes of the *International Classification of Disease*, this number underestimates the real figures, even for high-income countries, and does not include drownings that occur as a result of floods, tsunamis, and boating accidents.”(Szpilman, Bierens, Handley, & Orlowski, 2012)

Drowning is a significant cause of death among boys from 5 to 14 years worldwide. In the United States, it is the second leading cause of death for children 1 to 4 years old. In other parts of the world, the incidence of drowning can be 10 to 20 times as high as in the United States. In Thailand, the death rate from drowning among 2-year-olds is 107 per 100,000. Globally, the risk factors for drowning are male sex, an age of less than 14 years, alcohol use, low income, poor education, rural residency, aquatic exposure, risky behavior, and lack of supervision. Individual medical conditions can also play a role – the risk of drowning for people with epilepsy is 15 to 19 times the risk for those who do not have epilepsy. In terms of its economic effects, incidents of coastal drowning alone are estimated to cost more than $273 million per year in the United States and more than $228 million per year in Brazil (Szpilman et al., 2012).

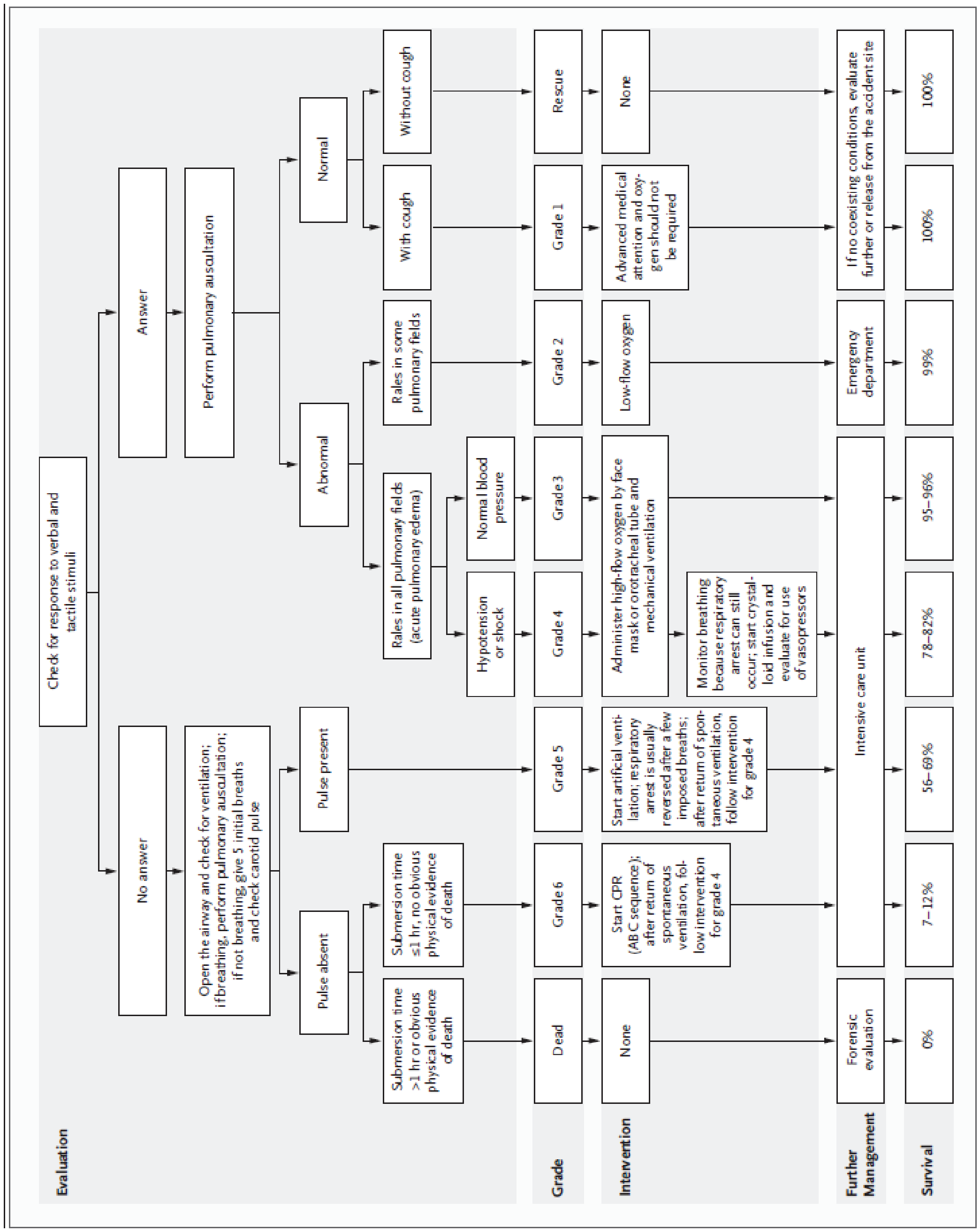

Figure 1. Emergency medical care steps for drowning victims

(Szpilman et al., 2012)

2.2.2 Choking

Despite its frightening reputation, foreign-body airway obstruction (choking) is potentially the most reversible acute emergency imaginable (Kloeck.W, 2007). However, quick response is critical to administer life-saving care in the event of choking. Once the airway is totally blocked, progressive hypoxia develops immediately and are rapidly followed by unconsciousness and death unless immediate relief is provided. This medical emergency is particularly pernicious because it is difficult to predict. It can potentially happen to anyone at any time, regardless of that person's health, physical condition, sex, or age. For this reason, it is beneficial for emergency medical procedures for treating choking to be well-known by the general population.

For the purposes of emergency education, choking incidents can be separated into two general categories: conscious victim and unconscious victim. In the case of a conscious victim, as long coughing, talking, or breathing is possible, the victim should be encouraged to cough vigorously. The victim should be left untouched, but should not be left alone even momentarily.

If the victim is not able to cough, talk or breathe, help is necessary in the form of the Heimlich maneuver (Fig 2). The maneuver is administered by standing or kneeling behind the victim and placing a fist around the victim's abdomen just above the navel. The fist is clasped firmly with the other hand and both are brought upward and inward together in a sharp abdominal thrust. This action may be repeated 5 times if necessary.

Figure 2. The Heimlich maneuver

If the 5 abdominal thrusts are unsuccessful, the victim should be leaned forward and up to 5 back slaps should be administered by using the palm of the hand to hit the upper back between the shoulder blades. If still unsuccessful and the victim remain conscious, the 2 actions mentioned above should be repeated up to 5 times.

If the victim loses consciousness, emergency medical assistance should immediately be called. The victim should be laid on his or her back, with head tilted back and mouth open. Any foreign material visible in the airway should be removed with great care taken so as not to push the material further down. At this point, the victim should be checked for signs of breathing. Figure 2 shows the technique used for the Heimlich maneuver provided by the Resuscitation Council of Southern Africa.

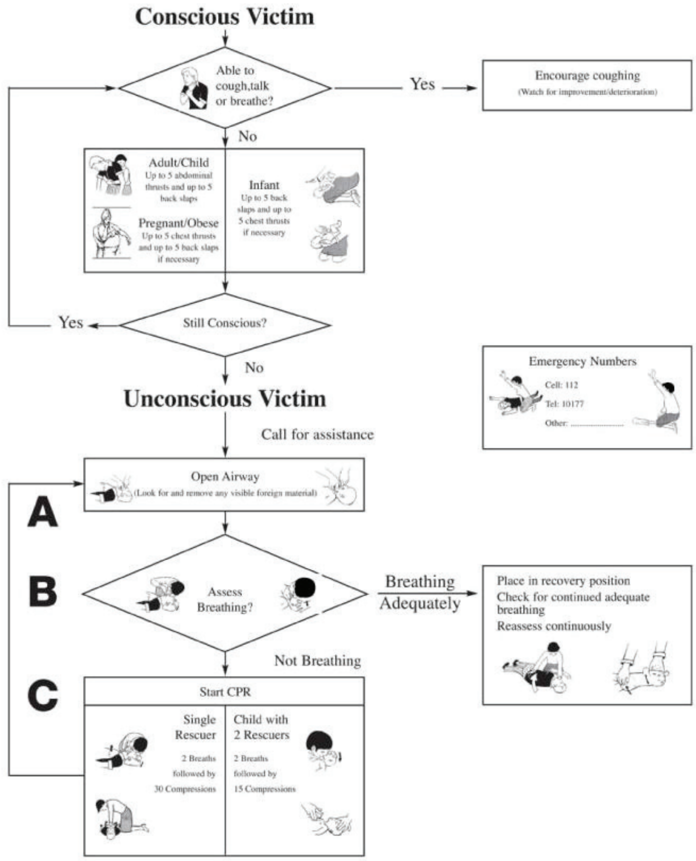

Figure 3. Protocols for treating choking

2.2.3 Bone fracture

Every year roughly 2 million people are admitted to emergency rooms (ERs) in the United States with long-bone fractures (LBF). Most of these patients present with moderate to severe pain (Minick et al., 2012). The majority of patients in Minick's 2012 study received inadequate pain management while in the ER. Future explorations of this topic ought to focus on disparities in pain management in the ER setting and examine possible causes in order to ultimately improve patient care.

Another study of fracture pain examined records of ER patients with extremity or clavicular fracutres to determine overall analgesic use, compare analgesia use between adults and children, and compare analgesia between the subset of those adults and children with documented moderate or severe pain (Brown, Klein, Lewis, Johnston, & Cummings, 2003). Of 2,828 patients with isolated closed fractures of the extremities or clavicle, 64% received any analgesic and 42% received a narcotic analgesic. Severe pain scores were recorded for 59% of visits overall, 47% of children younger than 4 years, and 34% of children younger than 1 year. Among patients with moderate or severe pain, 73% received an analgesic and 54% received a narcotic analgesic. Compared to adults, a lower proportion of children (≤15 years) received either any analgesic or a narcotic analgesic ($P<.001$).

The study concluded that, for pediatric and adult patients, ER treatment does not include pain medications frequently. Additionally, ERs were found not to record pain severity scores adequately. Pediatric patients were least likely to receive analgesics, especially narcotics. (Brown et al., 2003)

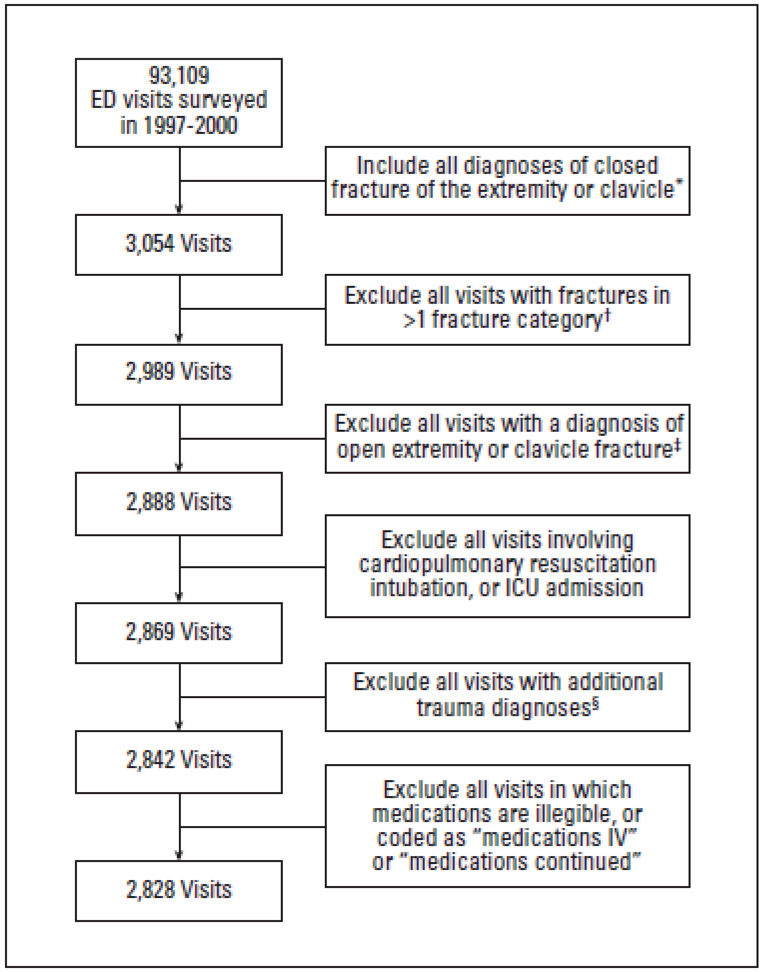

Figure 4. Numbers of patient visits included and excluded from Brown and Klein study

2.3 3D Visualization and Animation in Medical Care

"Three-dimensional computer generated imagery (CGI) provides the contemporary digital artist with the tools and techniques to build virtual sets and characters in the fields of film visual effects (VFX), animated features, and video games" (Kerlow, 2004). In recent years, 3D visualization and animation technologies have been increasingly applied to the field of medicine not only in research and clinical roles, but also educational ones. 3D volume visualization is one visualization technology which has recently become the focus of aggressive research due to increasing computational power available for contemporary computer visualization programs.

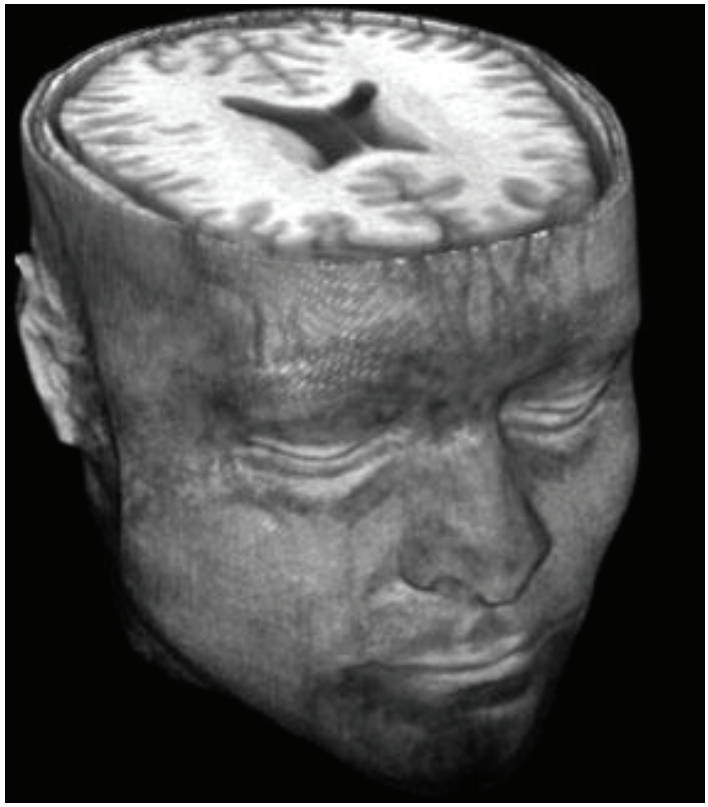

Figure 5. 3D volume visualization of the author’s head and brain from fMRI data acquired at Ninewells Hospital, Dundee, UK using OSIRIX visualization software

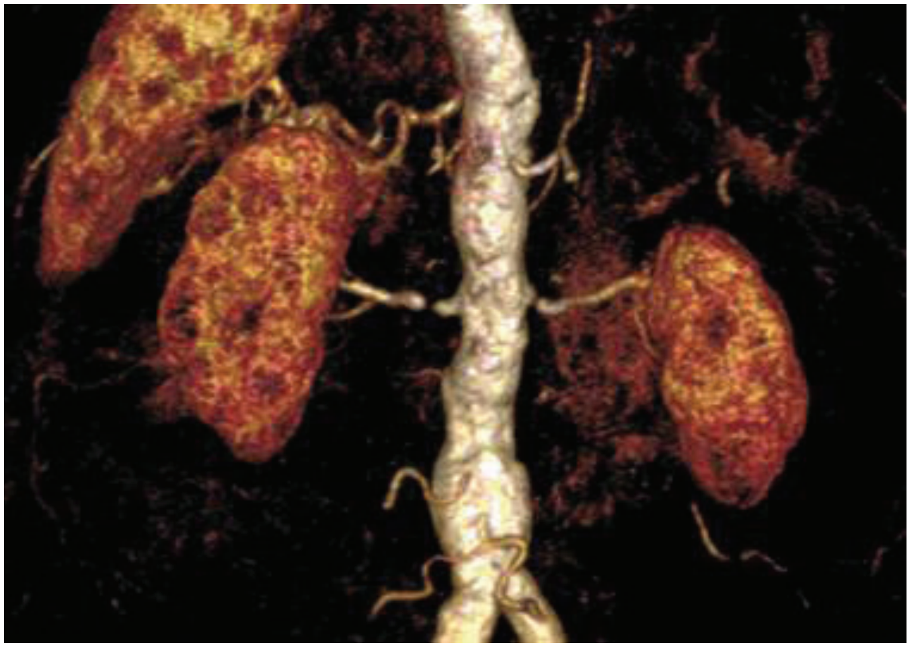

Figure 6. 3D volume computer visualization of MRI renal and splenic angiogram data acquired at Ninewells Hospital, Dundee, UK

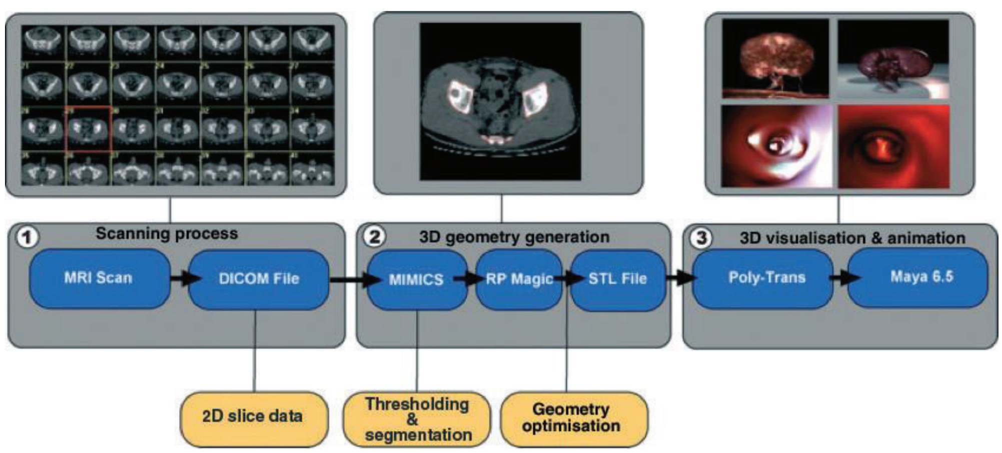

Figure 7. Illustration of staged pipeline process for visualization of raw data produced from clinical MRI

The marching cubes algorithm has been identified as the most appropriate method to complete the 3D reconstruction process (McGhee et al. 2007). MIMICS (a software package that facilitates the thresholding, segmentation and 3D meshing required for making MRI or CT into 3D geometry) has been used to allow translation of MRI scan geometry to a form accessible in MAYA 3D imaging software. Fig. 7 highlights each stage of the pipeline developed during this research project.

In another study (Wang et al., 2015), "a software application was developed by various experts, including urologists and human-computer interaction specialists, to serve as a video-based educational tool emphasizing narrated animations to promote understanding of terms related to urinary, bowel, and sexual function. This application was viewed by patients recruited from 2 low-income safety net clinics. Fifty-six patients with a mean literacy level of 7th to 8th grade completed the study. Patients achieved statistically significant improvements in comprehension for the majority of the terms after the video intervention, with notable improvements including the terms "incontinence" (from 14% to 50%), "bowels" (from 14% to 46%), and "impotence" (from 58% to 84%)." The study concluded that this video-based educational tool is an effective method for overcoming a severe lack of comprehension of health terminology among patients. These results point to a promising future for video-based educational tools, especially in cases where 3D animation-based tools share commonalities with the video-based tools mentioned in the study, as the advantages of 3D animation technology can readily be imported to video-based tools.

In a recent study, a randomized controlled parallel trial investigated the effect of 3D animation on the increase and recall of knowledge on periodontitis by patients with periodontitis (Cleeren, Quirynen, Ozcelik, & Teughels, 2014). The study conducted a comparison between the effects of a 3D animation (3D animation group) and narration and drawing (control group) (see Figure 8 for an example of the study materials). The experiment consisted of four steps: (1) a pre-test (to assess baseline knowledge), (2) each patient receiving one type of education (3D animation or control video), (3) a post-test (to assess knowledge immediately after viewing the video), and (4) a follow-up test (to assess knowledge recall after two weeks). Each test contained 10 multiple-choice questions. The results of this study demonstrate that 3D animations are more effective than real-time drawings for periodontal patient education in terms of knowledge recall. Thus, 3D animations may be a powerful tool for assisting in student information retention.

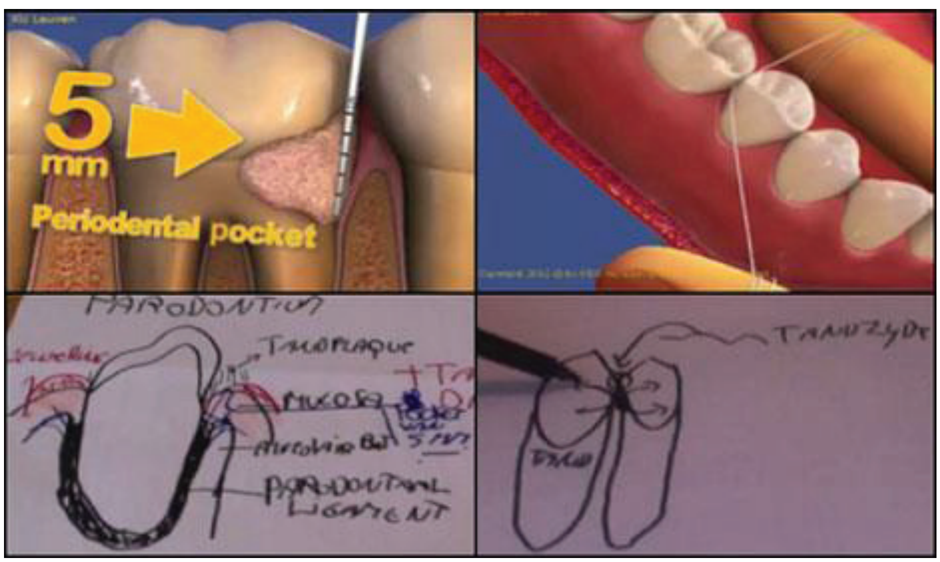

Figure 8. Screenshots from 3D animation (top) and sketches (bottom); a vestibular view is given in the sketches while 3D animation allows for multiple viewing angles

Another recent study compared the skill retention of an intervention group to a control in a single blind randomized controlled trial (Choa et al., 2009). Participants were randomized into two groups, the AA-CPRII group (n=42) and the control group (n=38). Both groups were asked to perform three cycles of CPR while their performances were recorded on video. Each group was comprised of laypeople (non-medical professionals) who had had their most recent CPR training at least six months before the experiment. The intervention group was given animation-assisted CPRII(AA-CPRII) instruction on their cellular phones, while the control group received no aid and were forced to rely on whatever they could recall from their previous training. A checklist was used by three evaluators to assess the educational animations. The psychomotor skills of participants were also evaluated.

The results of this study show that the AA-CPRII group had a significantly better score than the control group ($p < 0.001$). In terms of psychomotor skills, the AA-CPRII group demonstrated better performance in hand positioning ($p = 0.025$), compression depth ($p = 0.035$), and compression rate ($p < 0.001$) than the control group. The researchers note with optimism that "animation-assisted CPR could be used as a reminder tool in achieving effective one-person-CPR performance."

2.4 Animation in Education

With the advent of computers, animation has begun to play an increasingly important role in the classroom. Animation can be used not just to give clear illustrations of the objects of study, but also to enhance student engagement. For teachers, the attraction provided by the interactive capabilities of computer animation allow for greater classroom control and student focus (Xiao, 2013).

Study supports this assessment. According to researchers Vernon and Peckham, “Models have been used to teach human anatomy for over a thousand years. More recently technology has started to displace this traditional way of teaching with the development of visually rich and often interactive three-dimensional (3D) computer-generated images.”(Vernon & Peckham, 2002) In their study, Vernon and Peckham explore the value of using computers and specialist software to create 3D anatomical and biological models as well as their possible influence in facilitating medical education and publication. The study concludes that 3D models, though expensive to produce, possess the key virtues of being easy and cheap to share electronically. In addition, the virtual models have the potential to give students the opportunity to gain limited surgical experience without any danger to patients via simulated surgical environments. The study’s conclusions also note that application of 3D modeling and animation allows the visualization of subjects and scenes that could never be captured on film.

One study demonstrated this by using educational animations to teach players the odds of winning a slot machine and the benefits of pre-commitment (Wohl, Santesso, & Harrigan, 2013). These are relatively complex mathematical topics, but the 3D medium enabled teachers to convey them in short, simple forms.

In the study, two educational animations – one 3 minutes long, another 9 minutes – were designed to teach two principles related to gambling and probability: (1) to dispel false theories about how slot machines operate; and (2) to explain that slot players are almost certain to lose money over time (Wohl et al., 2013). Because of its shorter length, certain items were cut from the 3-minute animation, including a segment using the example of a conveyor belt to illustrate the probability of winning a slot machine payout. While the study's comparisons between 9-min and 3-min versions are not pertinent to this study, its conclusions regarding the suitability of animation for educational purposes were taken into consideration when designing the 3D animation used in this study.

Figure 9. Screen shot of (a) the conveyor belt metaphor and (b) the bag of marbles metaphor depicted in the 9-min educational animation

Figure 10. Screen shot of the bag of marbles metaphor depicted in the 3-min educational animation

Another study reviewed the pedagogical experience obtained with systems for algorithmic animation to demonstrate helpful applications of educational animations in the classroom (Esponda-Argüero, 2008). An algorithm is a set of well-defined steps, described using a formal language, which transforms input data into output data. The algorithms in this study consisted of a sequence of operations whose effect on data structures could be visualized using a computer. The study required students to follow an animation through multiple different operational steps to learn algorithms. These algorithmic animations improved students' understanding of algorithms, but mainly when the students were able to engage as active participants rather than as passive spectators.

This study highlighted the difficulty of teaching the code used in the implementation of a specific algorithm. However, test-runs can be used to help students understand the mechanics of an algorithm's code. Since effective pedagogical practices aim not just to illustrate concepts clearly, but also to make them easy to remember, algorithmic animations were also used to help students recall the mechanics of an algorithm after having seen it a limited number of times.

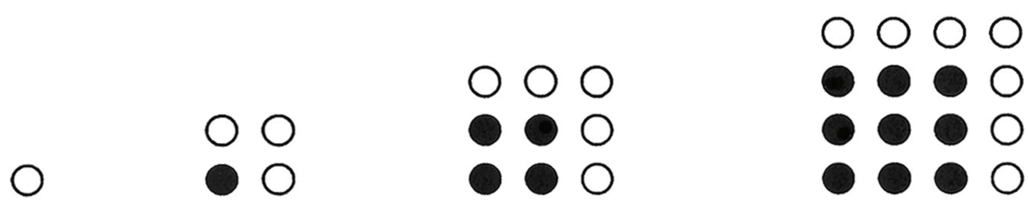

Figure 11. "Proof without words:" the sum of successive odd integers is the square of the number of integers in the sequence

Two examples in the study demonstrate the benefits of algorithmic animation. In the field of mathematics, there is a long tradition of producing "proofs without words" – that is, demonstrating proofs visually. The first example from the study employs the sequence consisting of the sum of successive odd numbers: 1, 1+3, 1+3+5, 1+3+5+7, and so on. The sum of the numbers in this sequence is the square of the number of integers included in the sequence. A "proof without words" visualization aids greatly in teaching this concept (see Figure 11).

Another example which illustrates the potential of educational animation involves a proof for the Pythagorean Theorem. When two squares are drawn inside one another (as in Figure 12), a triangle with sides *a* and *b* and hypotenuse *c* repeats four times inside the larger square. From this, the Pythagorean Theorem can be derived.

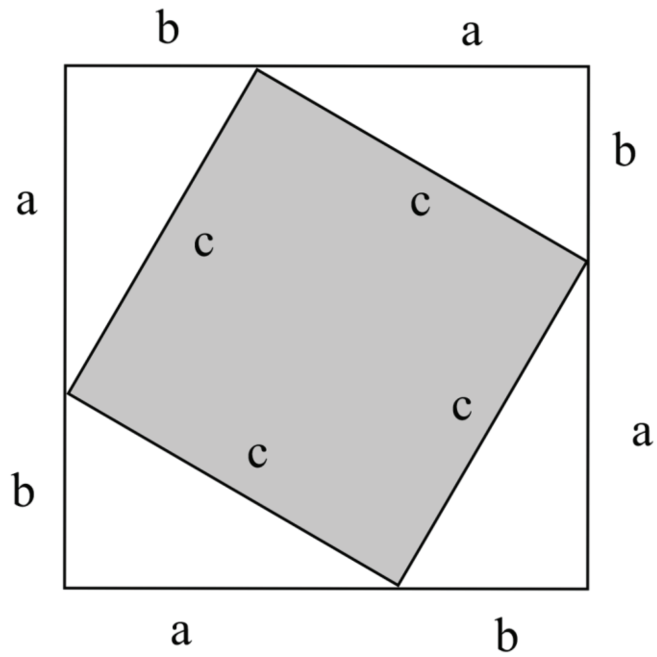

Figure 12. “Proof without words:” Pythagorean Theorem

Research has also been done to broadly compare traditional education systems and systems that employ multimedia. One study compared teaching methods based on reading textbooks and receiving verbal instruction to those using interactive multimedia (Islam, Ahmed, Islam, & Shamsuddin, 2014). In this study, three groups of students from a primary school in Dhaka city were taught with three different educational styles. One group of participants was taught with traditional education tools (textbook and lecture instruction). The second group was taught with only visual learning materials, while the final group received a blended education program employing an interactive video and the teacher’s instructions. The interactive blended approach resulted in the greatest acquisition and retention of knowledge (Islam et al., 2014).

Richard Meyer posits that 12 principles shape the design and organization of multimedia learning materials in the book *Multimedia Learning* (Cambridge Press, 2001). These principles can act as a guide for the exploration of animation's educational applications in this study. They are as follows:

Coherence calls for the exclusion of words, pictures, music, sounds and symbols that are interesting but irrelevant or unneeded in a multimedia presentation in order to improve the student's learning.

Signaling suggests that people learn better when they receive cues in the organization of multimedia materials that direct attention to the most important information. This signaling reduces unnecessary effort and confusion by building a systematic structure that allows the learner to connect to key materials.

Redundancy dictates that people learn better when provided with graphics and narration rather than a combination of graphics, narration and printed text. The visual channels of human brain can be overloaded when scanning between pictures and text or trying to compare material in multiple visual forms.

Spatial Contiguity asserts that when relevant words and pictures are near to each other, rather than far from each other, students learn better. This way, learners do not have to use cognitive resources to connect the corresponding pictures and words.

Temporal Contiguity describes another aspect to presenting corresponding words and pictures: they should be presented simultaneously, rather than successively. When they are presented simultaneously, learners are more likely to retain their association.

Segmenting dictates that a message presented in user-paced segments helps learning better than a message presented in a single continuous unit. A user-paced message gives learners enough time to fully comprehend the content, while a long continuous unit does not.

Pre-training provides the idea that a multimedia message is more deeply understood when learners already know the names and characteristics of the concepts. When learners try to mentally construct a causal model of the system, pre-training helps manage the mental demand by distributing some processing to a pre-training episode.

Modality is the principle that a combination of pictures and spoken words will help learners better than a combination of pictures and printed text. Because pictures and printed text enter the brain through the same channel of visual perception, they can overload cognitive systems.

The principle of Multimedia states that people learn better with words and pictures than with only words. Verbal and visual mental models are constructed when pictures and words are presented and a connection between them is built at the same time.

Personalization posits that giving a conversational style to the words in a presentation works better in helping students learn than giving them a formal style. When learners feel the presenter is talking to them, they are more likely to believe and remember the words from the presenter as a partner.

Voice contends that people will learn better when the narration of the multimedia is spoken in a friendly human voice rather than a machine voice.

Image suggests that people won’t necessarily benefit from a multimedia lesson when the speaker’s image is added to the screen.

2.5 Summary

One important purpose of the research in this study is to design and create a 3D animation that can aid healthcare students' comprehension of emergency medical care. This 3D animation will be tested to determine its educational efficacy.

The animation will cover the topics of drowning, choking and bone fracture, which are common medical emergencies with a variety of serious consequences including death. However, there are many other medical emergencies that can also have severe results. These three specific emergencies are picked not only because of the broad dangers they pose globally, but also because their treatments are suitable for visualization in a 3D animation.

This chapter concludes with a discussion of design strategies in multimedia education materials. These concerns will be noted in the creation of an experimental methodology aimed at determining the effectiveness of 3D educational animations.

CHAPTER 3. METHODOLOGY

3.1 Introduction

The purpose of this study is to determine whether 3D animation can help healthcare students learn emergency medical care better than they can via traditional educational methodologies. Two factors in this study deserve special consideration: first, the time required for a student to internalize knowledge of the medical emergency treatments s/he is taught. The time includes the learning time, which should be the lecture time and the time of animation playing, and the practicing time. And, second, the ability of the student to put this knowledge to work when confronted with these medical emergencies, and this ability is explained with four criterions: Accuracy, Speed, Completion and Order. Both factors are analyzed at the conclusion of the study.

This study assesses the efficacy of the educational animation by examining two educational approaches: lecture-based education and animation-based education. To preserve the experimental validity of the study, an ex post facto experimental design which includes both a treatment and control group and requires information to be recorded both before and after the experimental group is exposed to the educational material.

3.2 Research Approach and Hypothesis

This study compares two teaching styles: one employing traditional educational techniques and another based on the use of 3D animation. Both teaching approaches in this study are used to teach the same material, e.g, best practices for responding to the three medical emergencies described above. For the purposes of this study, “traditional education” refers to an oral lecture presented by a teacher in the classroom complemented with referrals to text books and hand drawings on a blackboard or whiteboard. The variables analyzed in this study include:

Dependent variables: evaluation of the performance (according to the criteria of Completion, Speed, Order, and Accuracy). Additionally, the subjective comments of the participants were recorded and are discussed in the conclusion.

This study is designed to employ a purely quantitative approach to compare traditional education and 3D animation education. Analysis of the quantitative data produced from the study will be used to accept or reject the experimental hypotheses:

H_0: The 3D animation of emergency medical education does not improve the participants’ learning of emergency medical care.

H_1: The 3D animation of emergency medical education improves the participants’ learning of emergency medical care.

To test the hypotheses, the two groups will be compared in male/female gender cohorts. In addition to the four aforementioned criterions (Accuracy, Speed, Completion, and Order), one more metric will be used: Total. This represents the total of the four separate scores.

To assess each criterion individually, ten secondary comparisons of experimental data will also be made. These sub-hypotheses are:

H_{10}: The 3D emergency medicine education animation does not improve the male participants' Accuracy scores in the test.

H_{11}: The 3D emergency medicine education animation improves the male participants' Accuracy scores in the test.

H_{20}: The 3D emergency medicine education animation does not improve the male participants' Speed scores in the test.

H_{21}: The 3D emergency medicine education animation improves the male participants' Speed scores in the test.

H_{30}: The 3D emergency medicine education animation does not improve the male participants' Completion scores in the test.

H_{31}: The 3D emergency medicine education animation improves the male participants' Completion scores in the test.

H_{40}: The 3D emergency medicine education animation does not improve the male participants' Order scores in the test.

H_{41}: The 3D emergency medicine education animation improves the male participants' Order scores in the test.

H_{50}: The 3D emergency medicine education animation does not improve the male participants' Total scores in the test.

H_{51}: The 3D emergency medicine education animation improves the male participants' Total scores in the test.

H_{60}: The 3D emergency medicine education animation does not improve the female participants' Accuracy scores in the test.

H_{61}: The 3D emergency medicine education animation improves the female participants' Accuracy scores in the test.

H_{70}: The 3D emergency medicine education animation does not improve the female participants' Speed scores in the test.

H_{71}: The 3D emergency medicine education animation improves the female participants' Speed scores in the test.

H_{80}: The 3D emergency medicine education animation does not improve the female participants' Completion scores in the test.

H_{81}: The emergency medicine education animation improves the female participants' Completion scores in the test.

H_{90}: The 3D emergency medicine education animation does not improve the female participants' Order scores in the test.

H_{91}: The 3D emergency medicine education animation improves the female participants' Order scores in the test.

H_{100}: The 3D emergency medicine education animation does not improve the female participants' Total scores in the test.

H_{111}: The 3D emergency medicine education animation improves the female participants' Total scores in the test.

3.3 Procedure

Each participant in the study progressed through four steps: group assignment, pre-test, education and post-test. Before any participant took part in the study, its experimental parameters were subject to an Institutional Review Board (IRB) review and approval.

All participants in this study were asked to respond to a simulated medical emergency. This performance, which required the participants to act out their response by interacting with a volunteer or medical model, was recorded and evaluated by a medical expert. After the pre-test, participants in one group received the traditional education about these medical emergencies, while members of the other group watched the 3D animation. After, both groups completed a post-test which was identical to the pre-test. Comparing participant performance on the post-test to the pre-test allows for an assessment of learning gain.

3.4 Participants

Because the author of this study has a preponderance of professional relationships in China which allow for greater ease in terms of logistics and resource acquisition, this experiment was conducted at a medical school in China. All of the participants are first-year pupils who had no professional background in emergency medicine (with the exception of those who may have achieved some knowledge of emergency medicine through their own extracurricular efforts). All participants were nursing majors.

The two participant groups used in the experiment were the same size, contained students in the same year of schooling, and had the same percentage of males and females. The participants were randomly selected among first-year students, they had similar grades, learning ability, and level of background knowledge relating to medical emergencies on average. Each group was made up of 30 students for a total of 60 participants in this study.

3.5 Data Samples

The performances of each student in both pre-test and post-test were graded by an expert from the department of Nursing who was either a teacher of an emergency medicine class or a nurse in a hospital's department of emergency medicine. The graders evaluated the students' performances according to four criteria: accuracy, speed, completion and order. Accuracy refers to how accurately the students were able to perform the procedure compared to literature practices (e.g., whether they touched the right position on the victim's body, etc.) Speed refers to how quickly the students performed the treatment and also whether they used proper rhythm for chest compression and face-to-face breaths: in general, prompt and quick emergency medical care is crucial for patient survival in medical emergencies, though the rhythm for the specific activities mentioned cannot be too quick or it can cause harm to the patient. Completion refers to whether the students were able to finish the treatment without omitting any important procedures. Order refers to whether the steps of the medical treatment are administered in the proper order – some actions used for emergency medical care may waste time or cause harm if they are not performed in the correct sequence. All four criteria were rated from 1 to 5, with 1 standing for poor knowledge and inadequate performance and 5 standing for excellent knowledge and perfect performance.

3.6 Pre-test

The research in this study focuses mainly on the learning progress of the students and thus also on the efficacy of the teaching methods employed. For this reason, pre-tests and post-tests were administered before and after the educational intervention, respectively. Analysis of the data from the test was used to draw conclusions regarding the extent to which each student's knowledge improved.

In the pre-test, each participant was asked to deal with three different medical emergencies: drowning, choking, and bone fracture. Subjects were asked to perform pre-hospital first-aid for these three medical emergencies on educational human body models, which are the same size as the real human body. Each participant was timed during their performance (it should take about five minutes to deal with the three medical emergencies). While the participants performed their treatments, emergency medicine professionals carefully observed their actions. The professionals were asked to evaluate the performances for each participant, assigning a grade for each of the criteria described above.

3.7 Education

Subjects were divided into two groups: control group and experimental group. The control group received traditional education in the form of a lecture from a classroom instructor. Though individual instructors' lecture speeds vary, the lecture material typically took about 20 to 30 minutes to cover, including a question & answer session at the end of class. The experimental group watched the 3D animation about emergency medical care education created for this study, which lasts approximately 10 minutes. For the purposes of this study, the learning times for each method are considered fixed: 20 to 30 minutes of class time for the lecture group, and less than 10 minutes for the animation group. Both lessons gave equivalent information for treating drowning, choking, and bone fracture.

After the lecture or animation, students were encouraged to practice what they had just learned on medical human models. This was optional – they were allowed to decide whether or not they wanted to practice, and, if so, how long they would want to practice. While practicing, the graders were present in the room to answer students' questions. To ensure fairness, graders were instructed to answer only the exact question that the student asked and not to provide any further teaching nor any knowledge beyond the scope of the question. Students were allowed to move on to the post-test at any time as long as the graders were not busy testing others.

3.8 Post-test

After the two groups of participants received their lessons, both were asked to come back for a post-test, which was exactly the same as the pre-test. In addition, participants in the experimental group were asked to complete a survey that included demographics questions, questions on previous experience with 3D animation and questions that investigated the participants' attitude toward the technology.

A detailed analysis of the results is presented in the next section.

3.9 Survey Structure

After the post-test, the participants of the experimental groups who had just viewed the 3D animation were asked to take a survey. This survey mainly focused on the attitudes of the healthcare students toward multimedia education. The survey also assessed whether participants had previously experienced lecture-based traditional education techniques in their normal learning and had experienced 3D animation education for the first time in the experiment. This allowed us to better assess both whether the 3D animation had an influence on the healthcare students untainted by earlier educational experiences with 3D animation and also whether healthcare students were open to the possibility of multimedia education.

Each participant took 5 to 10 minutes to complete the survey. The survey consisted of two parts: personal background and attitudes towards 3D animation. In the personal background section, the information requested included not only age and gender, which are needed to assure demographically valid research results as well as to plan for future research, but also the participant's background relating to emergency medicine and 3D animation technology. These were necessary to determine whether the 3D animation in the study is the sole animation contributing to participants' results on the tests and also to determine whether the healthcare students were receptive to 3D animation-based education.

In the attitudes towards 3D animation section, the questions focused on subjective comparisons between traditional education and 3D animation-based education. Questions attempting to ascertain the following were asked in this part of the survey: which kind of education the participants prefer and which benefits the participants value most in each kind of education. The answers to this part of the survey helped to draw conclusions about the attitudes of healthcare students towards 3D animation education compared to the traditional education system.

A final question at the end of the survey attempted to generate data that might make the 3D animation more educationally effective in the future. The question asks participants to describe which medical emergencies might be suited for 3D animation teaching. Ideally, the treatments for these emergencies should be neither too long nor too short; similarly, they should be neither too complex nor too simple.

The survey is included in the Appendix.

3.10 Statistical Data Analysis

Experimental data provided three categories of information: the participant's gender, the group the participant belonged to, and the scores the participant received on the test. T-test comparison was implemented between the two groups for participants of the same gender and also based on shared scoring criteria. For example, if the experimental group is Group A and the controlled group is Group B, the male students in group A can be called AM and the females can be called AF, while in group B they can be called BM and BF, respectively. Our comparison attempted to find the difference between the teaching styles when applied to similar groups. Thus, our model employed two T-tests: AF vs BF and AM vs BM. Additionally, each of the four standards (accuracy, completion, speed, and order) received a T-test to assess differences between participants based on their scoring profiles. Because two total score values were calculated by adding the individual scores for the four criteria, ten two-sample T-tests were conducted to produce ten P-values in the analysis portion of this study.

Normally, a comparison of the P-value and the type I error α, which is set as 5% in this study, would demonstrate the effects of the different teaching styles. However, in this study, the Holm-Bonferroni method is used to account for the multiple comparisons. This method is designed to control the overall type I error and provide a simple test more powerful than the Bonferroni correction. The method is as follows: for a given significance level α, order the p-values from lowest to highest, $P_1 \ldots P_m$, and let the associated hypotheses be $H_1 \ldots H_m$. Let k be the minimal index such that. The null hypotheses $H_1 \ldots H_{k-1}$ are rejected and hypotheses $H_k \ldots H_m$ are not rejected. If k=1, all null hypotheses are not rejected. If no such k exists, reject all of the null hypotheses.

3.11 Summary

This chapter gives an overview of the experimental study used to assess the efficacy of 3D animation in teaching emergency medical topics. The variables of the study are enumerated, the data sampling methods employed are described, and the experimental procedure is provided. A hypothesis and null hypothesis are proposed. At the end of this chapter, the proposed methods used for statistical analysis are discussed.

CHAPTER 4. RESULTS

4.1 Introduction

This chapter first presents the implementation of the experiment, including how the subjects were divided into two groups and how the preliminary data was collected. Second, data analysis is presented. This section gives an overview of how the data is analyzed statistically using R software. Finally, there is a brief analysis of the additional results from the answers to the questionnaire.

4.2 Experiment Implementation

The experiment was conducted in a medical school in China, and all the participants were students from Department of Nursing. The experiment began with a pre-test for all the participants, which was designed to determine what initial knowledge the students had about topics in medical emergency. When the experiment was designed, the number of the participants was expected to be 60: 30 students for each group. However, 68 students took part in the pre-test and all of them finished the entire process. The pre-test asked each student to deal with the three medical emergencies. For drowning, a medical model with the shape of a human body was put on the ground in the classroom, and the student was asked to do what they knew about drowning treatment to help the "person." For choking, a teacher of the department pretended to be choking, and the student was asked to deal with the situation. For lower bone fracture, each student was asked to help a person pretending to lie on the ground with a bone fracture.

After pre-test, the 68 participants were divided into two groups. There was a roster with the names of the students in that class, and each of the students had a number on the roster from 1 to 68. The 68 numbers were then divided by odd and even. At this time, everyone was given the questionnaire mentioned in Chapter 3.

Once the subjects were grouped, one of the two groups were taught by a lecturer, Mrs. Li, who is an experienced teacher and a skillful nurse. The lecture took place in the department's practicing room, which is designed for these action-oriented lessons. Figure 13 and Figure 14 below are pictures from the class. Meanwhile, the other group went to a multimedia classroom and watched the animation designed for this research. The animation took about 5 minutes and the lecture took about 20 minutes. However, at the request of the students in the experimental group, the animation was played three times before the students went to the next section, practice.

Figure 13&14. Pictures of the traditional medical emergency lesson.

After the two groups received their medical emergency education, they went on to practice. There were two practicing rooms, one for each group. While they were practicing, two teachers, both experts in medical emergency, stood in each room answering questions. The teachers would not teach anything even if they saw something wrong when the students were practicing. The students had at most one hour to practice considering there were only four models in each room and 34 students were waiting to use them. When the test began, the teacher in the practicing room became the examiner and graded the students’ performance on the questionnaire. The students could take the test as long as the teacher was available within that one hour.

Once the participant took the test and answered the questions on the questionnaire, they could return questionnaires to the researcher and leave. Then the experiment was over. Thus, the experiment measured four scores for each student: Accuracy, Speed, Completion, and Order.

4.3 Statistical Data Analysis

The R language and software were used for statistical analysis. R is a programming language and software environment for statistical computing and graphics supported by the R Foundation for Statistical Computing (Ihaka, 1998). Before the statistical analysis, the raw data was edited into a format that is readable for R language and software and easily programmed. Figure 15 shows how the data was edited and saved in the computer. Each row stands for one student's information in this experiment. Under the Group column, "A" indicates the experimental group, which is the group that watched the animation before the test. "B" indicates the controlled group. As for Gender, "F" is female and "M" is male. The Total column is the sum of the four scores previous.

Group	Gender	Accuracy	Speed	Completio	Order	Total
A	F	3	4	3	3	13
A	M	4	5	4	4	17
A	M	4	5	5	4	18
A	M	4	5	4	5	18
A	F	2	3	3	2	10
A	F	4	4	5	5	18
A	F	2	4	3	2	11
A	F	3	4	3	4	14
A	F	4	3	4	4	15
A	F	3	4	4	3	14
A	F	3	4	4	3	14

Figure 15. A portion of the edited data.

T-tests were performed to determine whether there is a significant difference between Group A and Group B. Considering that there are four criteria, there were four T-tests: namely, T-tests between Group A and B of Accuracy scores, Speed scores, Completion scores, and Order scores. In addition, for more precise results, the four T-tests were divided by male and female for a total of eight. In other words, each T-tests was run between different groups, but within the same gender. Along with the four criteria, this study counts the "Total" as another criterion in the statistical analysis. Therefore, in total, there are ten T-tests in the statistical analysis. This study uses a combination of two capital letters to stand for these T-tests. The first letter contains the information of Gender, and the second stands for the one of the four standards. For example, FA means the T-test of the females' Accuracy scores between Group A and B. MC means the T-test of the males' Completion scores between Group A and B. As mentioned before, T stands for the criterion "Total."

From the ten T-tests, ten P-values were generated. According to the Holm-Bonferroni method mentioned in Chapter 3, these P-values were compared to the adjusted type I error. Figure 16 shows a table containing the ten P-values and the adjusted type I errors.

FC	0. 000296593	0. 005
FT	0. 008096514	0. 005555556
FO	0. 01414724	0. 00625
MT	0. 01866027	0. 007142857
FA	0. 0535976	0. 008333333
MO	0. 1019395	0. 01
MC	0. 1334047	0. 0125
MA	0. 2105753	0. 016666667
FS	0. 2364586	0. 025
MS	0. 3506167	0. 05

Figure 16. P-values of the ten T-tests. (First column are the T-tests, second column are P-values, third column are adjusted type I errors)

Mean	Accuracy	Speed	Completion	Order
AF	3.074074	3.592593	3.555556	3.555556
AM	4.166667	5	4.166667	4.333333
BF	3.592593	3.925926	4.37037	4.259259
BM	4.5	4.875	4.75	5

Figure 17. Means of different groups.

As evidenced by the table, only the comparison of the Completion scores of females (FC) indicates a significant difference. The remaining results are not significantly different. Combined with Figure 17, a table containing the means of the data, we may conclude that among those female students, those who completed traditional education improved their knowledge of medical emergency better than the animation-education students in the aspect of Completion. The rest of the comparisons present no significant differences from a statistical perspective.

4.4 Additional Results

Besides the scores of the pre-test and post-test, the answers to the questionnaire enlightened the researcher greatly, and possibly produced ideas for future research on both animation education and medical education.

Members of the experimental group were asked to answer the questionnaire, and fortunately, all of them cooperated. When asked their opinion of animation education, most students showed a positive attitude and looked forward to its improvement.

The first question on the questionnaire asks whether the participant is familiar with basic first aid knowledge. Most of the students answered “yes.” This suggests that most of the students have gained cursory knowledge of emergency medical procedures from a broad assortment of sources that may include the internet and TV as well as school.

Interestingly, a wide variety of medical emergencies are mentioned in their answers, including sports injury, drowning, and coughing up blood.

The second question asks whether they have been previously taught using animation as a teaching tool. The majority of the answers to this question were “no.” It is possible that some of the respondents have watched animations about medicine before (for instance, on TV or the internet), but it seems that in the academic setting, 3D animation is basically new to them.

One question asked the students how to improve the animation education from the perspective of their medical experience. The most useful answer, which more than one student answered, is that an interactive interface with better simulation of real human actions would greatly improve the quality of the education. In future work, there might be an operating system with good navigation connecting educational animations. The concept of “animation” may even be changed to an “educational game.”

As for the pros and cons of the animation, the majority of participants thought that animation is a vivid and attractive way of presenting information, giving the students a better motive to go to class. On the other hand, they also mentioned that the animation is not detailed enough for them to see the exact position of the human body. Many of the students’ answers present a similar complaint that they couldn’t see some of the positions and actions very clearly. This problem caused some confusion when they were trying to understand the animation.

As this study was designed, a major question was, “Which kinds of medical emergencies can be studied in this research?” The timing of the animation, the complexity of the treatment, the popularity of the emergency, and the presentation of the movements — every one of these factors was important. Thus, picking a medical emergency that fit all these criterions was difficult. So, in the questionnaire, the same question was asked to see if some ideas would emerge from the respondents' medically-trained minds. Fortunately, there were some specific answers. Asthma and epilepsy were the two most common responses. Other medical emergencies, like heatstroke, internal bleeding, and burns were also mentioned by some participants. However, it seems clear that all of these emergencies should be the focus of study and careful planning before they become animations. Future work will definitely focus on these answers.

CHAPTER 5. CONCLUSION

5.1 Conclusions from Statistical Analysis

The most important results generated from the experiment are the comparisons between different groups for the four criteria. Based on Figures 16 and 17 in the previous chapter, we may conclude that only the comparison of the Completion scores of females between Group A and B indicates a significant difference. This shows that, from a broader perspective of overall learning effect, the two methods of education are not very different. In other words, the teaching effect of traditional lecture-based education is not significantly different from that of animation-based education. From Figure 17, we may conclude that the experimental group has a lower score than the controlled group. However, the differences are not significant enough to conclude that the lecture-based education is better than animation-based education. In this case, the result is good.

Some objective factors may contribute to the results. First, the difference between the scores is considered to reflect the difference in influence between two methods of education. Yet, the influence of a teacher was not considered in the result. Under the teacher's supervision, the students might be listening more carefully or focus more on the information. Conversely, when the experimental group watched the animation, no one supervised them except the researcher, who had no influence on those students. Another factor relates to the designer and creator of the animation. It was the animator's first time doing work that concerns education. Meanwhile, the teacher of the lecture-based education was very experienced in teaching. This difference in the experience of teaching may result in a difference that cannot be ignored. Thirdly, the skill of the animator may not be equivalent to the teaching skill of a teacher who has been teaching medical emergency for many years, and this difference can influence the results greatly, even it is not unavoidable under the circumstances. In conclusion, considering these factors that may cause a significant difference, the T-tests show a good result and are promising for the future of animation education.

5.2 Participants' Comments

As mentioned in Chapter 4, some of the participants' answers greatly enlightened the researcher. These results not only showed the opinions of the participants towards animation education, but provided some good ideas that will possibly help future work in animation education and medical education. The students looked forward to taking this kind of lesson again and showed great interest in animation education. However, although they presented a preference toward animation education, they still stated some shortcomings of this method.

5.3 Future Work

Lecture-based education has existed for hundreds of years, and through the years it has never ceased improving. Surely there are explanations for why it cannot be replaced. Animation-based education is no doubt a new teaching method, but it has a power that attracts both teachers and students. This research is aimed at exploring the potential of animation in education.

In the future, there will be several directions in which animation-based education can be greatly improved. First of all, from the perspective of animation technology, the animation in this study still causes some confusion among the students according to the participants' comments. The actions in the animation are not displayed clearly, and also some of the positions are not marked obviously. To solve these problems, more camera movements and better camera positions are needed. And surely there is always space for the actions of the characters to improve. Besides these, the quality of the images matters greatly. Perhaps in the future the researcher should spend more time and effort on the rendering process. Improving the animation is a way to explore and learn, as well as a way of improving teaching quality.

From the perspective of medicine, the answers to the questionnaire will make an essential contribution to future work. The participants provided this study with several choices of medical emergencies to be chosen in the future. For example, asthma. "Asthma is a common long term inflammatory disease of the airways of the lungs." (WHO, 2016) "There is no cure for Asthma" (WHO, 2016), "Symptoms can be prevented by avoiding triggers, such as allergens and irritants, and by the use of inhaled corticosteroids." (NHLBI Guideline, 2007) There are also some other diseases that can be represented in the animation, requiring cooperation between animators and medicine teachers. Thus, better communication between people skilled in technology and people skilled in medicine is necessary in the future.

Besides animation and medicine, education plays an irreplaceable role in this research. However, in the analysis of the results, this study did not pay much attention to the influence of the teaching skill. To improve the effect of educational animation, educational skills and communications with students must be developed to a higher level. In this case, a long term cooperation with a medical school would help greatly. Furthermore, the researchers should not simply stay in front of a computer and work with teachers. An interaction with not only the teachers but students will provide researchers with more visions and ideas, some of which would never have entered their minds otherwise.

APPENDIX

APPENDIX

Experimental Questionnaire

Gender：

Time taken：

Questions:

1. Have you ever been acquainted with medical emergency care or pre-hospital first aid?

2. Have you ever been taught with the help of 3D animation? In other words, have you ever been shown a 3D animation to teach some new concept or procedure?

3. Compared to animation-assisted education, what advantages and disadvantages do you think that traditional lecture-based education has?

4. Was any part of this animation confusing to you?

5. From your perspective as a healthcare student, do you have any suggestions to improve this animation?

6. Drowning, choking and bone fracture were chosen for this animation because their causes and the procedures for their treatment lend themselves to the strengths of 3D animation. As a healthcare student, what other medical issues do you think can be taught via educational animation?

Test grades：

1. Accuracy: (1-5) Refers to the precision of the student's performance.
2. Speed: (1-5) Refers to the student's pace while performing; treatment steps cannot be taken too quickly nor too slowly.
3. Completion: (1-5) Refers to whether the student misses any treatment steps or not.
4. Order: (1-5) Refers to whether the steps in the student's treatment are in the right order.

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