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Bleeding Control Using Multiple Amputee Trauma Trainer In Medical Simulation Comparison Of Movement Versus Non-movement In Training

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BLEEDING CONTROL USING MULTIPLE AMPUTEE TRAUMA TRAINER IN MEDICAL
SIMULATION: COMPARISON OF MOVEMENT VERSUS NON-MOVEMENT IN
TRAINING

by

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ABSTRACT

Army first responders, specifically Combat Medics and Combat Lifesavers, provide medical intervention while in the field. Didactic as well as hands-on training helps to prepare these first responders, and one module they receive involves bleeding control. First responders are taught to use the Combat Application Tourniquet® (CAT®) to stop bleeding from limbs subjected to severe injury such as amputation, gunshot, or severe lacerations. A training aid like the Multiple Amputee Trauma Trainer™ (MATT™) simulator provides tourniquet training using a lifelike bilateral lower limb amputee. In addition, MATT™ combines movement and resistance while the first responder applies the tourniquet, mimicking conditions one would see in a real situation.

This research describes tourniquet history, appropriate usage, field tourniquet review, surgical tourniquet, CAT® bleeding intervention procedures, bleeding physiology and complications, prehospital tourniquet use in recent conflicts, medical simulation fidelity, and a review of the value of animatronic movement during tourniquet simulation-based training. I then evaluate the effectiveness of animatronic movement during tourniquet training using the Advanced MATT in an experiment using Army first responders. The control group experienced no movement while the experimental group experienced movement when applying a tourniquet during the lab-training. Each group then alternately experienced Advanced MATT movement during an immersive scenario along with fog, strobe lights, and battle sounds. It was hypothesized that 1) In the immersive scenario, the experimental groups (i.e., those who were trained on a moving simulator) would have a *faster reaction time* as compared to those participants who did not receive training on the moving Advanced MATT simulator; 2) In the

lab-based training, the experimental groups would have a *slower reaction* time; 3) In the immersive scenario, the experimental groups would have a *faster tourniquet application time* when subjected to movement while in the lab-based training, but the experimental groups would also have a *slower tourniquet application time* when initially subjected to movement in the laboratory-based training; finally, 4, 5, and 6) Participants who completed lab-based tourniquet training on the Advanced MATT simulation with animatronic movement would report *higher perceived realism scores* than participants who complete the training on a static version of the Advanced MATT and participants who completed a tourniquet training immersive scenario on the Advanced MATT simulation with movement would report *higher perceived realism, presence*, and *self-efficacy scores* than participants who complete the training on a static version of the Advanced MATT.

The empirical results show a significant overall training effect of the Advanced MATT simulator (with or without movement). For reaction time and tourniquet application time, involving simulator movement was significant over varying scenarios. A small reduction in reaction and tourniquet application time on the battlefield may be extremely beneficial on the battlefield. Participants who received movement generally gave more positive reactions than those who did not received movement, although these results failed to reach statistical significance. Participants who received movement, followed by a scenario without movement rated the subjective ratings the lowest, suggestive of the lack of movement. Furthermore, despite the order movement was received, no large drops in performance occurred in any condition, indicating that negative training was avoided.

To Mom and Dad who taught me to work hard, persevere and that I could become anything I set

my mind to be.

To Dillon and Emma, I cannot wait to see you grow up. The sky is the limit!

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LIST OF ACRONYMS/ABBREVIATIONS

AAR	After Action Review
AHS	Active Hemorrhage Simulator
AMEDD	Army Medical Education Doctrine Department
ANOVA	Analysis of Variance
ARMEDCOM	Army Reserve Medical Command
BAS	Battalion Aid Stations
CAT®	Combat Application Tourniquet®
CLS	Combat Lifesaver
CSH	Combat Support Hospital
CUF	Care Under Fire
DCMT	Department of Combat Medic Training
EMT	Emergency and Military Tourniquet
EMT-B	Emergency Medical Technician-Basic
FRSS	Forward Resuscitative Surgery System
FST	Forward Surgical Team
HapMed	Haptic Medicine
HPS	Human Patient Simulator
HRED	Human Research Engineering Dimension
IED	Improvised Explosive Device
IFAK	Individual First Aid Kit
IRB	Individual Review Board
IT	Improvised Tourniquet
LRT	Last Resort Tourniquet
MAT	Mechanical Advantage Tourniquet
MATT	Multiple Amputee Trauma Trainer
METI	Medical Education Technology Incorporated
MMU	Multiple Medical Unit
MOS	Military Occupation Specialty
MSTC	Medical Simulation Training Center
NCD	Needle Chest Decompression
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
ONT	One-Handed Tourniquet
PDA	Personal Digital Assistant
PTSD	Post Traumatic Stress Disorder
ROI	Return on Investment
RPG	Rocket Propelled Grenade
SATS	Self-Applied Tourniquet
SBIR	Small Business Innovative Research
SME	Subject Matter Expert
SOFTT	Special Operations Forces Tactical Tourniquet

ST	Surgical Tubing
STP	Shock Trauma Platoon
STTC	Simulation & Training Technology Center
TBI	Traumatic Brain Injury
TCCC	Tactical Combat Casualty Care
TFC	Tactical Field Care
TRADOC	Training and Doctrine Command
UCF	University of Central Florida

CHAPTER ONE: INTRODUCTION

First Lieutenant David R. Bernstein lost his life in 2005, despite quick care from military first responders and rapid transport to a surgical medical facility (Little 2005a). However, if 1LT Bernstein had had a Combat Application Tourniquet® (CAT®) applied to his leg wound, he might have survived.

Battlefield casualties are an unfortunate consequence of military service. In particular, severe trauma to extremities may account for 50% of the injuries related to combat (Champion et al., 2003; Patel et al., 2004), and bleeding, resulting from these traumatic battlefield injuries, is among the leading causes of death (Champion, Bellamy, Roberts, & Leppaniemi 2003; Bellamy, 1984). However, military first responders, or those personnel with combat medical training, can potentially reduce the number of bleeding limbs with timely tourniquet application.

Throughout the first few months of 2005, probes by the Senate inquired why tourniquets were not given to Soldiers (Little, 2005b); this was followed by a campaign by the Pentagon, ordering over 172,000 tourniquets for Army Soldiers and Marines (Bowman, 2005). The Tactical Combat Casualty Care (TCCC) doctrine now directs liberal tourniquet use within operational doctrine (Parsons 2010). Battlefield military physicians found that casualties arriving with tourniquets had a better chance of survival than those without the device (Little, 2005c).

A testament to the tourniquet is the story of SGT Justin Farrar. SGT Farrar was assigned to accompany and protect CBS reporter Kimberly Dozier in Bagdad, Iraq in 2006—just one year following the tourniquet distribution to the Soldiers. As Beadle recounts the story, Memorial Day 2006 appeared as an ordinary day until, at the first stop, an Improvised Explosive Device (IED)

exploded, quickly followed by a second explosion. Most of the involved personnel died from the attack, except for SGT Farrar and Ms. Dozier. Both had tourniquets applied, and both survived. SGT Farrar attributes a tourniquet, applied by a medic, for saving his life (Beadle, 2010).

In contrast to military settings, tourniquets are rarely used in civilian traumatic injuries. Instead, civilian procedures call for direct pressure to be applied to the injury. Yet, the next two individuals may have benefited from a tourniquet. The first, a 40 year-old male, was involved in a "high-speed motor vehicle accident" with femoral leg bleeding not controlled by direct pressure (as well as other sustained injuries). Once at the hospital and in shock, the bleeding still did not stop, and he died in the operating room. The second individual, a 27 year-old male, received a gunshot wound to the thigh. Again, direct pressure did not stop the bleeding. Despite transfusions and medical interventions in a hospital setting, he also died (Langley & Criddle, 2006).

It is possible that both of these individuals may have lived if a tourniquet had been applied. Despite direct pressure, in both cases, so much blood had been lost by the time surgery occurred, the medical professionals could not save these patients. Tragically, tourniquet application was discussed in both cases but was rejected in favor of more customary measures (Langley & Criddle, 2006).

Army First Responders

In the Army, first responders include Combat Medics and Combat Lifesavers (CLSs). Army Combat Medics (also referred to as Medics or 68W Health Care Specialists), provide the

necessary medical treatment to sustain Soldiers during a combat mission, while the CLSs are non-medical personnel who have received limited lifesaving skills instruction and who can facilitate self-aid and "buddy-aid" in trauma situations (Parsons, 2010). Furthermore, they assist Combat Medics, helping to close the gap in treatment time on the battlefield.

Medical skills are perishable. Therefore, CLSs and Medics require routine opportunities to practice key medical procedures, such as tourniquet application. Traditionally, first responders practice tourniquet application on makeshift training devices, such as a 2x4 wrapped with carpet or antiquated part-task trainers. Although this helps large numbers of students experience tourniquet application, it can have negative training effects, since wood and hard surfaces do not effectively simulate limb soft tissue. Alternatively, training facilities may have trainees apply tourniquets to each other. Although the human body is higher fidelity than blocks of wood, it still yields negative training as the tourniquet is only tightened to the pain tolerance of the individual, which may not be indicative of the true torque pressure needed to stop a dynamic wound.

New tourniquet full-body patient simulators and part-task trainers may be better solutions. They provide injury realism with visual cues of severed limbs and dynamic bleeding that can be controlled by tourniquet pressure. Additionally, incorporating movement into these simulators may enhance their realism, further improving tourniquet training and enhancing battlefield tourniquet application. The present research focuses on CLSs and Combat Medics, with secondary focus on other medical personnel (e.g. physician assistants and nurses) and their application of a tourniquet to a moving hemorrhage simulator.

Medics and CLSs receive different levels of training. CLSs take a three-to-four day course where they receive didactic instruction and hands-on lab-based scenarios, various

"buddy" exercises, and practice with mannequins and part-task trainers varying in fidelity. In contrast, Combat Medics are Emergency Medical Technician-Basic (EMT-B) certified, and they go through a rigorous 16-week Combat Medic course consisting of TCCC doctrine. The Medic student program involves both cognitive/written skills testing, and students must pass all with a 70% or higher. By way of comparison, the CLS students must only pass a written cognitive test (with 70%) and receive a "go" on their skill testing (Parsons, 2010).

Although physicians receive more extensive training than first responders, it is important that these personnel understand combat-related injuries and the initial treatment given on the battlefield. Many of these medical personnel serve in Battalion Aid Stations (BAS) and Forward Surgical Teams (FST) inside the battle zone or Combat Support Hospitals (CSH) outside the battle zone. They may apply or re-apply tourniquets in an attempt to triage large numbers of casualties.

This paper discusses the literature review of the tourniquet, usage, traumatic amputation, medical simulation fidelity, and animatronic movement in section two. Section three describes the methodology and research design for the MATT study. The last few sections include results in section four, a discussion of the results in section five, and conclusions in section six.

CHAPTER TWO: LITERATURE REVIEW

This section provides an overview of the tourniquet and other traumatic amputation bleeding interventions relevant for the current research. *Traumatic amputation*, in this report, refers to an amputation during a battlefield enemy engagement. Amputation may result in *exsanguination* (i.e., bleeding to death), which is one of the main causes of preventable death on the battlefield (Beekley, Starnes & Sebesta, 2007; Beekley et al., 2008; Parsons, 2010; Champion et al., 2003; Bellamy, 1984; Butler, 2007; Parsons & Walters, 2004).

Although this research focus on tourniquet application in the military realm, tourniquets can also prove helpful in events such as the Columbine shootings, World Trade Center, Oklahoma City Federal Center bombing, other urban-style conflicts, as well as in rural, farm-based injuries where there is great distance to transport to hospitals (Walters et al., 2005). In these civilian mass casualty events, tourniquet application may be one of the only interventions able to stop bleeding on the "civilian battlefield." Rescue officials may not enter buildings unless cleared by police and egress to hospitals may be slow, mimicking the chaos that occurs on the battlefield (Butler, 2003). These rescue personnel may not be able to apply direct pressure to the wounds of the mass, as typically seen in civilian trauma. As these types of events increase in civilian areas, the importance of "self- and buddy-aid" (Champion et al., 2003, p. S13) may give way to tourniquets as lifesavers for those caught in the military—or civilian—crossfire.

Tourniquet History

Tourniquets have a long history of use across many cultures, during which the tourniquet was alternatively praised and criticized by physicians, military officials, civilian first responders, and a range of other stakeholders. The Ancient Greeks first identified tourniquets as a viable bleeding control, and they were also used in the time of the Roman Empire. Later, in Europe, both German and French physicians used tourniquets during amputation (Moulin, 1998, as cited by Mabry, 2006). German surgeons further developed the *Spanish windlass,* an early form of the tourniquet (Hilden, 1646, as cited by Mabry, 2006), and the French were the first to use tourniquets in wartime, during the Siege of Besancon. The French also coined the term "tourniquet" while using the device for military surgery (as cited in LaDran, 1749).

The modern field tourniquet came from the birth of the historical tourniquet as well as the surgical tourniquet. It was the Battle of Shiloh during the Civil War, with large number of casualties, that lead to the decision for each Soldier to carry what we consider today to be an improvised tourniquet (i.e., wood and a handkerchief) (Mabry, 2006). There are many stories of successful tourniquet use during the American Civil War, but by the end of the war there was less support for tourniquets. Mabry reports that incorrect application and overuse, resulting from poor training, may be to blame for this lack of support. During more recent wars, beginning with Vietnam (Mabry, 2006), the tourniquet has shown "lifesaving benefits" with minor morbidity (Kragh et al., 2009b) and became popular due to its effectiveness on the battlefield (Doyle & Taillac, 2008). Furthermore, wider use of tourniquets in Vietnam may have prevented many deaths (Kragh et al., 2007). Tourniquets were used also used during the Korean conflict, Somali operations, and more recently with Operation Iraqi Freedom (OIF) and Operation Enduring

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Freedom (OEF) in Iraq and Afghanistan, respectively. Furthermore, these instances may have helped develop criteria leading to TCCC doctrine, with support of modern day tourniquets.

<u>Traumatic Amputation Bleeding Physiology</u>

As seen in previous wars, exsanguination during combat occurs over a "usual" time span of 5 to 10 minutes; this time may be affected as systolic blood pressure falls under 90 mm mercury (Hg) (Champion et al., 2003). This time may be as little as 2 minutes, in severe cases, if 1.0 to 1.5 liters of blood are lost in a minute (Wenke, Walters, Greydanus, Pusateri, & Convertino, 2005).

The majority traumatic amputations on the battlefield are caused by explosions, including IED, mortar, mine, rocket propelled grenade (RPG), bomb, and rockets (Brodie et al., 2007). Additionally, blood loss may occur due to gunshot and knife wounds, motor vehicle accidents, and burns (Beekley et al., 2007, 2008; Kragh et al., 2008, 2009). By reducing blood loss, the tourniquet may provide more time to reduce exsanguination, regardless of the cause of injury.

There are many components that affect a tourniquet's effectiveness to reduce and/or eliminate exsanguination. The tourniquet type, width, force, limb girth, and proper placement according to the limb injury are factors playing a role in successful bleeding control. Both surgical and field tourniquets function by compressing soft tissue, muscle, and surrounding blood supply to halt the arterial bleeding (Doyle & Taillac, 2008). This compression or "limb occlusion pressure is defined as the minimum pressure required, at a specific time by a specific tourniquet cuff applied to a specific patient's limb at a specific location, to stop the flow of arterial blood

into the limb distal to the cuff" (Noordin et al., 2009, p. 2961). According to Tejwani et al., tourniquet pressure is the easiest factor to modify (2006). The mastery of this skill and recognition of the application of force using a tourniquet allows a first responder to stop a casualty's bleeding in an effective and timely manner.

Differing force is needed to occlude smaller or larger limb girth sizes (i.e., limb sizes); for example, the leg versus the arm requires more force to occlude bleeding (Shaw & Murray, 1982). The relationship between tourniquet pressure and limb circumference is inversely related (Noordin et al., 2009; Shaw & Murray, 1982; Graham, Breault, McEwen, & McGraw, 1993). The force required is also related to the width of the tourniquet (Doyle & Taillac, 2008): The more narrow the tourniquet, the higher pressure needed to occlude bleeding; conversely, the wider the tourniquet, the lower the pressure needed to occlude bleeding (Noordin et al., 2009; Crenshaw, Hargens, Gershuni, & Rydevik, 1988; McEwen, Kelly, Jardanowski, & Inkpen, 2002; Graham et al., 1993). Force combined with tourniquet width and type also contributes to the possible "post-tourniquet" issues (Tejwani et al., 2006) that are seen in many of the improvised or tubing types of tourniquets due to their narrow design. The higher pressures required by narrow tourniquets can cut into the limb tissue and cause limb damage, as well as increased pain (Worland, Arrendondo, Angeles, Lopez-Jimenez, & Jessup, 2006). This pain is due to the force being distributed across a smaller area when compared to wider tourniquets. The knowledge of force application is important to the first responder when adapting to limb circumference and tourniquet type.

Ischemic Complications and Limb Damage

In casualty situations, fast battlefield extraction to a higher level of surgical care is important for avoiding the possibility of further limb damage. The use of a tourniquet does not necessary mean a patient will lose a limb, but as research has shown, the longer a tourniquet is applied, the narrower the tourniquet, and the higher the pressure used: the higher the risk for limb damage. There is much debate regarding tissue damage and the possibility of limb loss when applying a tourniquet. As commented in the previous section, tourniquets can be useful in battlefield and surgical settings if users are trained and the appropriate tourniquet is used. Tourniquets can reduce and prevent exsanguination, as well as lower morbidity (Kragh et al., 2009b). Nonetheless, there are still dangers to limb, soft tissue, and muscle, especially with extended use of narrow improvised tourniquets.

A study involving rabbits investigated "tourniquet application-induced skeletal muscle necrosis beneath the tourniquet." The tourniquets were left on the rabbits for two hours and researchers found that injury was reduced using the lowest possible inflation pressure (Pedowitz et al., 1991). The researchers suggest that these findings can apply to human clinical use as lower pressures may be achieved using wide tourniquets (as cited in Crenshaw, Hargens, Gershuni, & Rydevik, 1988; Jennische & Hansson, 1986; Pedowitz et al., 1993; Younger, McEwen, & Inkpen, 2004). This pressure reduction and wider cuff size theory is supported in a study consisting of twenty adults, where two types of pneumatic tourniquets were used to address occlusion pressure, tourniquet cuff size (both 14cm wide and 7cm narrow cuffs), and associated pain (Estebe, Le Naoures, Chemaly, & Ecoffey, 2000). The wide cuff usage was more effective and less painful than narrow cuffs when occlusion pressure was reduced (Pedowitz et al., 1993).

As seen from the literature, there is almost always risk to the limb when attempting to stop blood flow. The lack of arterial flow may result in *ischemia* (Lee, Porter, Hodgetts, 2007): tissue damage or tissue death from blood loss to an area. Ischemia may be reduced by decreasing the amount of time battlefield or pneumatic tourniquets are used, as well as by the type of tourniquet used. Additional training may further mitigate the risk.

Surgical Tourniquet Complications

Complications from the surgical tourniquet are both local and systemic in nature (Doyle & Taillac, 2008). Local complications may include "postoperative swelling and stiffness, delay in recovery of muscle power, compression neuropraxia, wound hematoma, wound infection, direct vascular injury, bone and soft-tissue necrosis, and compartment syndrome" (Wakai, Winter, Street, & Redmond, 2001, p. 243). *Peripheral neuropathy* is another complication thought to result from high occlusion pressure (Graham et al., 1993). This neuropathy affects the limbs and may result in loss of feeling, burning, tingling, or pain. In fact, the peripheral nerve may be most susceptible to the pressure of the tourniquet (Kragh, 2010). Additional systemic complication may include "increased central venous pressure, arterial hypertension, cardio respiratory decompensation, cerebral infarction, alterations in acid-base balance, rhabdomyolysis, deep venous thrombosis, tourniquet pain, systemic inflammatory response syndrome, and fibrinolysis" (Wakai, 2001 p. 243). Table 1 lists common complications, along with the respective suggestions for reducing damage (Langley & Criddle, 2006, p. 255). Again,

the type of tourniquet, as well as amount and time of pressure, may help to reduce the above listed complications.

During extremity surgery, two hours of "tourniquet time" is the generally recommended maximum application (Gidlof & Lewis, 1990; Navein, Coupland, & Dunn, 2003). If a tourniquet is applied more than six hours, surgical doctrine recommends amputation above the tourniquet to "reduce arrhythmias and crush syndrome (Navein, Coupland, & Dunn, 2003, 2003, p. S220). Furthermore, if a tourniquet has been applied for 12 hours or longer, the risk of gas gangrene increases (Navein, Coupland, & Dunn, 2003). It is not common to see tourniquet times greater than two hours in a surgical setting, but is possible during battlefield application accompanied with long transit times.

Table 1: Tourniquet Application Complications and Reductions

Complications	Reductions
Crush injury to the underlying tissues, particularly from tourniquets that are small or narrow.	Place the tourniquet as distally as possible, but at least 5 cm proximal to the wound.
Limb ischemia, that may necessitate amputation, In fact, amputation is recommended for any extremity that has experienced six or more hours of tourniquet time.	Avoid application over a joint.
Reperfusion injuries. These cause massive destruction of the injured limb's microcirculation.	Apply the tourniquet directly to the exposed skin. This will prevent unnecessary movement or slipping.
Gas gangrene, that can occur after long-term placement (>12 hours).	Release the tourniquet as soon as it is medically safe to do so. Tourniquet times of 2 hours or less rarely are associated with serious complications.

Note: All content quoted from Langley & Criddle, 2006, p. 255. Some of the suggestions to reduce complications are carried out by physicians (i.e. releasing the tourniquet), while placing a tourniquet distal is not recommended during Care Under Fire (CUF).

Field Tourniquet Complication

If complications occur in the surgical realm, with wider pneumatic tourniquets in a controlled environment, it would be logical to deduce that some of the same complications may be seen in the prehospital battlefield tourniquet. A few cases of battlefield complications have been discussed; however, "the only obvious effects of tourniquet use measured to date is that casualties are surviving more often despite worse injuries" (p. 30, as cited in Kragh et al., 2008, Kragh, 2009; Kragh, Baer, & Walters, 2007). Data on tourniquet use in Iraq show low rates of complications (Kragh, 2010). Although, those severely injured seem to benefit with tourniquet

application, even if not needed, negative limb damage is not observed as once thought to occur (Beekley et al., 2008). This further supports the use of the battlefield tourniquet as a "lifesaving" intervention that outweighs the possibility of ischemic complications (Tien et al., 2008). The reduction in negative limb damage may also be caused by the relatively brief transit time to CSHs—on average just 70 minutes, which is a substantial improvement from historical transit times (Beekley et al., 2007). This decrease in transit time to physician and surgical intervention may reduce adverse effects of tourniquet application such as tissue damage, limb loss, or neurological damage.

Although extended tourniquet use is not common, one exception was reported was during Operation Anaconda (Afghanistan) where multiple tourniquets (both military and improvised) were applied to a Warfighter's upper arm in excess of 16 hours without significant complications. In this instance, the casualty was also exposed to wind and cold temperatures including snow. This example demonstrates that it is possible to use a battlefield tourniquet for extend periods of time without substantial negative effects; it is possible that this warfighter escaped complications because of the cold temperatures and an incident where the wound bled again, called reperfusion (Kragh et al., 2007).

Furthermore, it may be argued that some complications may appear due to the traumatic nature of the injury. If limbs are lost, the tourniquet may not always be the sole reason (Kragh, 2009a). For example, 50% of complications involve superficial infection; it may be that infection could take place regardless of tourniquet use (Clasper, Brown, & Hill, 2009).

First Responder Actions during Care Under Fire

The following describes the actions under fire for a first responder. The first responder is limited in care while under fire. The application of a CAT® is the only first aid measure given until the casualty is moved out of the line of fire. It is important to understand first responder actions as it explains the background of field tourniquet application. Excerpt taken from CLS manual (Parsons, 2010, p. 2-1 – 2-2):

> When you are under effective hostile fire and see a wounded soldier who is also under enemy fire, you should do the following.
>
> a. Take cover and return fire.
>
> b. Suppress enemy fire. Reducing enemy fire may be more important to the casualty's survival than any immediate treatment you can provide.
>
> c. Try to keep the casualty from sustaining any additional wounds.
>
> d. Direct or expect the casualty to remain engaged as a combatant.
>
> e. Try to determine if the casualty is alive.
>
> f. If the casualty can function, direct him to move to cover, return fire, and administer self-aid.
>
> g. If the soldier has suffered an amputation or has serious bleeding from an extremity, direct him to apply the Combat Application Tourniquet® from his Improved First Aid Kit (IFAK) over his uniform and above the wound.
>
> h. If the casualty is unable to return fire or move to safety and you cannot assist him, tell the casualty to "play dead."
>
> i. Communicate the situation to your unit leader.

There are many tasks that the CLS and Medic perform. This research is interested in the task of tourniquet application to control for bleeding during CUF. Many bleeding related injuries can be controlled on the battlefield by affixing a tourniquet (Parsons, 2010). CLS and Medics must understand the cognitive steps involved in tourniquet application as well as the psychomotor skills required for successful completion of appropriate tourniquet use.

Appropriate Tourniquet Use

Tourniquets are recommended when there is a chance of bleeding to death from an arm or leg injury (Parsons, 2010). Although the application of direct pressure and elevation may manage the majority of extremity injuries and traumatic amputations, (Navein, Coupland, & Dunn, 2003) "current military doctrine dictates the use of a tourniquet as first line treatment for all 'life threatening' extremity hemorrhage during the first stage of Tactical Combat Casualty Care" (Beekley, Starnes & Sebesta, 2008, p. S34). The use of the tourniquet during TCCC (i.e., CUF, battlefield, or point of injury) is due in part to the inability to apply direct pressure or provide additional care because of enemy fire danger, large numbers of casualties, (Mabry, 2005) other essential duties (Kragh, 2010), the unknown extraction time (Kragh et al., 2007) to the next level of care, and/or the inability for some to move and return fire without use of a tourniquet (Navein, Coupland, & Dunn, 2003). Furthermore, the battlefield makes the additional levels of care given in the civilian arena impracticable to achieve (Bellamy, 1987; Butler, Holcomb, Giebner, McSwain, & Bagai, 2007).

This application of the tourniquet is the primary means to stop bleeding resulting from traumatic amputation (Parsons, 2010). As reported in OIF and OEF, it is important to note that liberal use of the tourniquet in the field and in surgical settings during triage is effective to control exsanguination. This research focuses on the use of the tourniquet in the "prehospital" (battlefield setting) with limited discussion on the surgical hospital setting.

The primary tourniquet carried by military first responders is the CAT®. It is commonly used during CUF, the initial and limited care that takes place during a hostile attack (PHTLS, 2005). The CAT® and other field tourniquets are discussed below, but first the more robust pneumatic surgical tourniquet is described.

Surgical Tourniquet

The *pneumonic "surgical" tourniquet* uses pressure in millimeters (mm), similar to a blood pressure cuff, to stop bleeding at the desired limb location. The pneumatic tourniquet device helps the surgeon achieve a "bloodless" environment (Pedowitz et al., 1993) and is applied during surgery to reduce blood flow during operations (Noordin, McEwen, Dragh, Eisen & Masri, 2009; Tejwani, Immerman, Achan, Egol, & McLaurin, 2006). The pressure cuff applies force via a pneumatic pump system in contrast to the prehospital CAT®, which uses manually operated strap system.

The pneumonic tourniquet could be interpreted as the "ideal" tourniquet. It uses the lowest pressure possible to stop bleeding (Tejwani et al., 2006; Pedowitz, 1993). It is wider, like a blood pressure cuff, and monitors blood pressure (unlike the field-use tourniquets).

Furthermore, differently sized wide cuffs may be used with the system (Wakai, Winter, Street, & Redmond, 2001; Kragh et al., 2008) as well as a contoured cuffs (McEwen et al., 2002) or curved cuffs (Pedowitz et al., 1993). Various cuff shapes and sizes may reduce the pressure at each area, theoretically reducing the risk of complications. The contoured cuff may be especially helpful with overweight or athletic individuals who have increased arm girth. However, despite these benefits the pneumatic tourniquet is impractical in the battlefield, partly due to the time needed to apply the proper type of cuff, monitor, and electricity constraints.

Field Tourniquets and Effectiveness

Not all tourniquets are the same, and only a few have proven effective in field conditions. In order to better understand battlefield bleeding control, King and colleagues conducted a literature review of field tourniquet performance and outline their suggestions for the ideal field tourniquet, which have differing requirements than the surgical tourniquet (King et al., 2006). The suggestions include: "effectiveness defined by complete occlusion of arterial blood flow to lower/upper limb; removable; rapid application under tactical conditions; easy to use under complete darkness; option to self-apply with one hand; ability to apply to a trapped limp; effective through multiple layers of clothing; minimal tissue necrosis and pain; comfortable enough to be worn for extended periods; light, portable, and compact; inexpensive; durable enough to withstand battlefield conditions; tactically appropriate in color; easy to manufacture with few or not mechanical parts; easy enough for the average Soldier to learn to apply with

confidence" (p. 1067). These criteria can be found in the CAT®, which explains why it is the tourniquet used by the military (as well as the device used in this dissertation).

Early studies using Special Operations Corpsmen (specialized Army 18-Delta trained) rank seven tourniquets for based on their placement, speed of use, ability to stop bleeding, as well as subjective assessment ranking the ratchet and bladder inflation/deflation. The ratchet is a metal system that tightens as the belting becomes captured within the mechanism, while the bladder consists of a pumping system (Calkins, 1999). This study was followed by other studies that explain why the windlass CAT® is now the tourniquet of choice for the majority of the U.S. Army.

Using a distal Doppler pulse signal (a device that measures pulse elimination), Walters et al. reviewed seven tourniquets with consideration to weight, durability, and comfort of the tourniquets (2005). Tourniquet selection characteristics included weight (no more than 230 grams), strap width (minimum of one inch, with two inches preferred), easy application (less than one minute), including ease of release and reapplication, no need for external power, as well as desired cost under $25 per unit (Walters et al., 2005). These characteristics are similar to those found in Table 2. The study concluded that the CAT®, Emergency and Military Tourniquet (EMT), and Special Operations Forces Tactical Tourniquet (SOFTT) were 100% effective in eliminating distal Doppler pulse, while the Mechanical Advantage Tourniquet (MAT) was effective 88%. The Last Resort Tourniquet (LRT), Self-Applied Tourniquet (SATS), and One Handed Tourniquet (H-Dyne) scored well under 70% effective with some reports of breakage as well as complaints of pain, pinching, slipping, and mobility constraints.

An additional study tested five different tourniquets: the SATS, One-Handed Tourniquet (OHT), Improvised Tourniquet (IT), EMT, and Surgical Tubing (ST). Although outside of the focus of this dissertation, the OHT may be a tourniquet to examine in future studies, with the understanding that its effectiveness is with upper extremity injuries only, using one hand to apply, for military and rural use. Through evaluation, the EMT and ST are the most effective for upper and lower pulse elimination, although the ST caused considerable pain. The OHT, IT, and SATS were not as effective in eliminating palpable pulse in the lower extremity, but the OHT was effective in occluding blood flow in the upper extremity (King, Filips, Blitz & Logsetty, 2006).

A third study examined the effectiveness of three tourniquets: sphygmomanometer, half-inch rubber tubing, and cloth and windless. This study researched ease of application, pain, and elimination of pulse. All three tourniquets were successful in cutting off distal pulse as measured via Doppler. The study's authors suggest that the criterion of pain be eliminated from future investigations, since stopping bleeding is most important (Swan, Wright, Barbagiovanni, Swan, & Swan, 2009). The importance is placed on fast and successful bleeding control, from tourniquets, as the use of pressure points, which may eliminate pain is not an option in the field.

It is worthy to note that in the above listed studies, environmental conditions were not addressed (i.e., mud, water, and blood). The aforementioned conditions may have a negative effect on CAT$^®$ application (Kragh et al., 2008). Since the CAT$^®$ is used in CUF to control bleeding, the three tourniquets (sphygmomanometer, half-inch rubber tubing, and cloth and windless) may not be as effective in controlling bleeding in a field environment. It is important to indicate that the CAT$^®$ has been shown to be one of the most effective tourniquets for multiple

characteristics, especially for lower limb injuries, which account for the majority of injuries (Lakstein et al., 2003). Overall, this research continues to demonstrate that the CAT® is among the most effective field tourniquets.

CAT® Tourniquet

The CAT® , displayed in Figure 1, is rated among the best in bleeding control, as well as width, weight, and cost (Walters et al., 2005); durability and effectiveness (Kragh, 2010); and it possesses many of the "ideal tourniquet" factors listed in Table 2 (King et al., 2006). CAT® is the chosen tourniquet for US and United Kingdom (Clasper, Brown, & Hill, 2009; Kragh, 2010). It is the primary tourniquet used by most Army first responders and, in 2005, was named one of the Army's top innovations (Kragh, 2010).
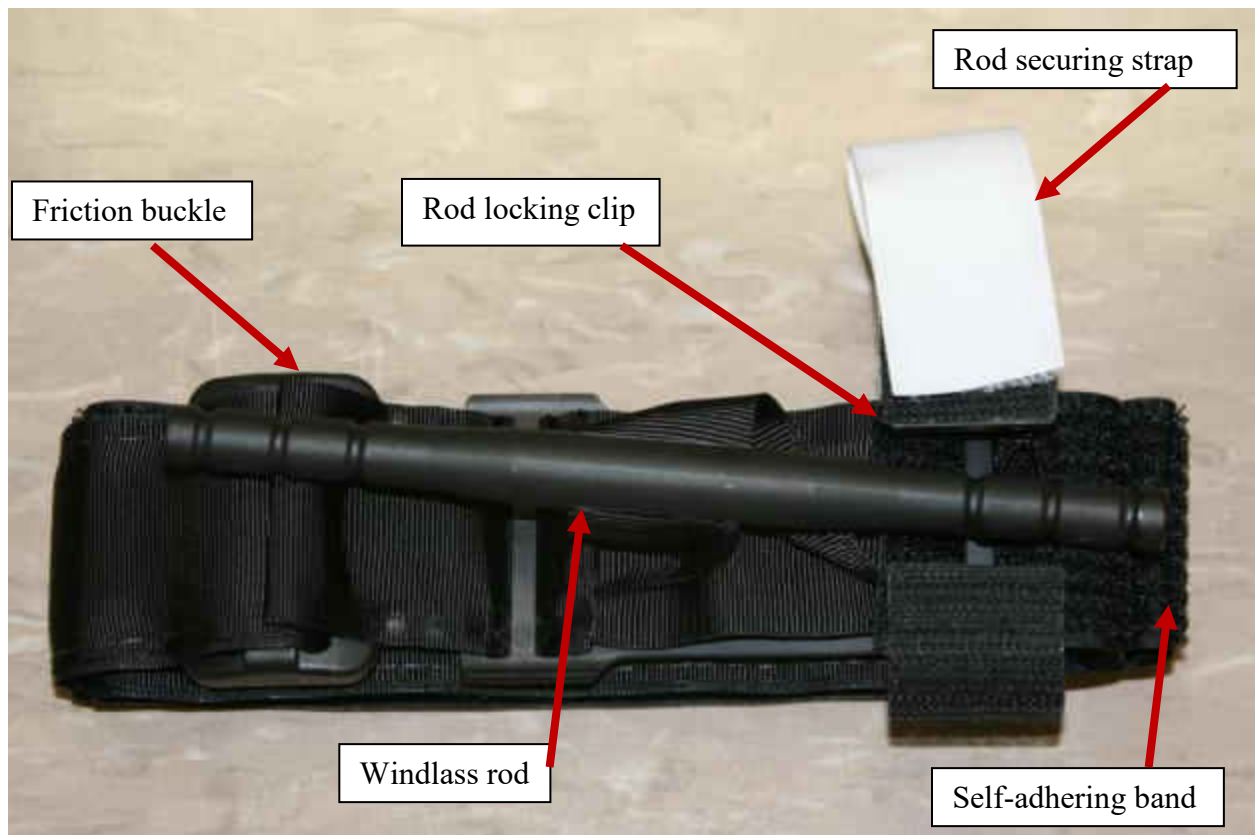
Figure 1: Combat Application Tourniquet®

Two-Handed CAT® Application

The following lists the procedure to apply a tourniquet, taken directly from the *CLS Handbook* (Parsons, 2010, pp. 5-14-5-15, 5-22):

> The two-handed application is normally used for the lower extremity when greater pressure is needed to stop the bleeding. The two handed application is always used when the tourniquet is applied to the casualty's thigh. The two-handed application is also used if the tourniquet band has become dirty since the friction buckle locks the band in place and help to prevent loosening during transportation.

1. Remove the CAT® from its pouch, Figure 2.

Figure 2: CAT® Removed From Package

2. Route the tourniquet band around the casualty's limb so that the band is two inches above the wound or as high as possible during CUF, Figure 3.

Figure 3: CAT® Routed High Around Limb

3. Pass the red tip of the tourniquet band through the inside slit of the friction buckle (Figure 4-8A) and pull the tourniquet band tight, Figure 4.

Figure 4: CAT® Routed Through Friction Buckle

4. Pass the red tip of the tourniquet band through the outside slit of the friction buckle, Figure 5. The friction buckle will lock the tourniquet band in place.

Figure 5: CAT® Routing Through Second Portion of Friction Buckle

5. Pull the tourniquet band until it is very tight and securely fasten the

tourniquet band back on itself, Figure 6.

NOTE: When the tourniquet band is pulled tight and secured, no more than three

fingers will fit between the tourniquet band and the limb.

Figure 6: CAT® Tightly Secured On Itself

6. Twist the windlass rod using both hands to tighten the tourniquet band, Figure 7. Continue tightening until the bright red arterial bleeding has stopped and the distal pulse is eliminated. The darker bleeding from the veins may continue for a while.

Figure 7: CAT® Twisting Windlass Rod

7.   Place the windlass rod inside the rod-locking clip, locking the rod in

place and keeping the tourniquet from untwisting, Figure 8.

Figure 8: CAT® Locking Windlass Rod

8. Check to make sure that the arterial bleeding has not started again and the distal pulse is still absent.

    (a) If arterial bleeding has resumed or the pulse is present, apply a second tourniquet proximal to the first tourniquet.

    (b) If a second tourniquet is applied, reassess to make sure the arterial bleeding is controlled and the distal pulse is absent. Do not remove the first tourniquet.

    (c) If the second tourniquet does not control the arterial bleeding, transport the casualty as soon as possible.

9. Secure the windlass rod and tourniquet band with the rod-securing strap, Figure 9. The CAT® is now properly applied and the casualty is ready for transport. If the casualty is not to be transported at this time, check the tourniquet periodically.

Figure 9: CAT® Securing Windlass Rod and Band with Rod-Securing Strap

10. Mark the casualty with a "T" on their forehead along with the time tourniquet was applied.

Tourniquet Effectiveness as Supported by Recent Conflicts

Until recently, few clinical studies had investigated the "effectiveness of tourniquets on hemorrhage control and casualty outcome" (Beekley et al., S28, 2008). However, in the last few years, leading physicians in actual military theaters have begun publishing more studies to answer questions of both tourniquet effectiveness and limb outcomes by tracking injured patients (see Beekley et al., 2007, 2008; Kragh et al., 2008, Kragh et al., 2009a; Kragh, 2010). In modern-era conflicts all around the world, similar injury patterns are seen with lower limb extremity wounds being most common. These extremity injury patterns are consistent with wars dating back to World War II (Champion et al., 2003; Patel et al., 2004), and are even more prevalent today. Presently, the U.S. military uses body armor that protects the chest and head regions. This reduces severe battlefield injuries (Carey 1987) but may increase extremity injuries (Bohman et al., 2005), as seen in conflicts such as Panama, Somalia, Iraq, and Afghanistan.

The assault on Punta Paitilla Airfield, Panama on 20 December 1989 resulted in numerous injuries and deaths to the six SEAL squads. During this conflict, the "control of extremity hemorrhage had the greatest positive impact on combat casualty care" (Mucciarone, Llewellyn, & Wightman, 2006, p. 690); in other words, the use of tourniquet on the SEALs "saved lives with no sequelae" (p. 690) or no consequences.

During the Battle of Black Sea, Somalia, tourniquets were used both in the field and at the CSH while casualties were waiting for surgery (Mabry et al., 2008). During this conflict, military personnel took heavy fire, and tourniquets were instrumental in controlling bleeding in the resulting mass casualty scenarios.

In Iraq and Afghanistan, extremity injuries accounted for over 50% of the injuries with 70% of tourniquet application occurring in the lower body limb region (Nelson et al., 2008). Between August and September 2004, as part of OIF, tourniquets were "liberally used on all patients involved in close range IED explosions with significant lower extremity fractures with no active hemorrhage identified at the time of presentation to the Shock Trauma Platoon (STP)" (Nelson et al., 2008, p. 212). Also during OIF, 165 patients with traumatic amputations with prehospital tourniquet application show improved hemorrhage control, especially with those more severely injured (Beekley et al., 2008). Surgeons note hemorrhage control benefits from seeing casualties arriving to theater hospitals with prehospital tourniquet (Beekley, Starnes & Sebesta, 2007). This hemorrhage control benefit may help those severely injured, as "57% of the deaths might have been prevented with earlier tourniquet use" (Beekley et al., 2008, p. S28).

In the introduction, 1LT David R. Bernstein lost his life, despite quick care from military first responders and transport within minutes of his injury to a surgical medical facility (Little, 2005a). Yet, if 1LT Bernstein had had a CAT® applied to his leg, he might have survived. Although difficult to quantify, the liberal use of tourniquets on extremity wounds in the field, applied earlier in the care cycle, along with the addition of FSTs, STPs, and the Forward Resuscitative Surgery System (FRSS) in forward areas of the battlefield may help save lives.

CHAPTER THREE: TOURNIQUET TRAINING

Medical Simulation History

Simulation, as defined by Maran and Glavin, "is an educational technique that allows interactive, and at times immersive, activity by recreating all or part of a clinical experience without exposing patients to the associated risks" (2003, p. 22). Participants interact as they would in a "real environment" with cues appropriate to their actions (Issenberg, McGaghie, Petrusa, Gordon, & Scalese, 2005).

Medical simulation grew from "flight simulation, resuscitation, technology, and plastics" fields (Rosen, 2008, p. 23) throughout its 34 year history (Issenberg et al., 2005). The first medical simulator was the "Resusci Anne," in 1960, which became a fixture in many CPR courses (Laerdal, 2010). Initially, Resusci Anne consisted of a woman's head and upper torso. This upper torso was very rigid, but eventually became more pliable, with a spring in the chest, accepting chest compressions while moving more naturally (Rosen, 2008). In the late 1980's and 1990's the medical field, with contributions from technology and innovators such as David Gaba, began to create full-body human patient simulators.

Historically, medical simulators have been used for surgical and anesthesiology training. Companies like Laerdal, Gaba, METI, and Gaumards made many contributions to the field, including creation of computer-based physiology models that mimic the human body (e.g., airway, breathing, bleeding, and labor simulation [Travis, 2009]). Contemporary examples include simulators for endoscopy, ear nose and throat, laparoscopy, endovascular, labor birth and

analgesia, urology, ultrasound, and ophthalmology (Innovation Learning Network, 2007; HelSim, 2008; Rosen, 2008; Magee, n.d).

<u>The Use of Simulation to Teach and Train Traumatic Amputation Bleeding Control</u>

Medical Simulation Training

There is a need for training to teach first responders to provide "care in a way that is medically and tactically astute" (Butler, 2003, p. S2). Training is important, and simulators may meet some of the needs in providing higher training preparation by using the right equipment to mimic battlefield injuries (Michel, 2009). Effective training that prepares first responders using simulation in environments comparable to those while deployed is necessary for skill development (Berry & Hilgers, 2004). As reported in previous sections, additional training for medics and first responders, specifically battlefield hemorrhage control is needed (Bellamy, 1984).

Simulators allow participants to practice their medical skills without the negative ramifications of errors (Pettitt, Norfleet, & Descheneaux, 2009). Simulation-based training offers cost and throughput benefits, too. As with aviation, medical simulation often costs less than live training (Estock, Alexander, Gildea, Nash, & Blueggel, 2006), and simulation gives first responders more opportunities to practice their skills. Trainees can repeat simulation scenarios multiple times and receive real-time feedback about their performance. Many medical and nursing schools (e.g., Stanford, Penn State, Wisconsin, University of Central Florida) now use

medical simulators as part of the training curriculum (e.g., Magan, 2010; Faulhaber; 2010, Travis, 2009; Slack, 2010). Medical simulators are also used heavily in the military to train first responders in a safe environment on procedures they are likely to perform on the battlefield.

The ability of training to provide relevant environments, complex and multi-casualty simulation scenarios comparable to those in the battlefield may help first responders keep their skills current, adapting to the environment at hand (Mabry, 2005). Training sites, such as the Department of Combat Medic Training (DCMT) and Medical Simulation and Training Centers (MSTCs), provide these types of all-encompassing experiences using battlefield sights, sounds, and smells. These intense training opportunities help the first responders to prepare for the possibilities of injuries they may treat.

Medical Simulators

Currently, there are many different types of simulators used in military medical training, some of which specially address hemorrhage control caused by extremity wounds such as traumatic amputations. Part-task trainers allow students to perform specific interventions within limited body regions (e.g., chest tube, cricothyroidotomy, or arm bleeding control).

Other part-task trainers include IV, Needle Chest Decompression (NCD), chest tube, and specialized surgical trainers (e.g. endoscopy, appendectomy, hernia, and laparoscopy), among others. The objective of the part-task trainers is to provide specific task training to the intervention at hand. They may be used in classroom lab-training or broken into module sessions for mastery of tasks.

<u>"Buddy Training"</u>

Human participants "buddy" training can also serve as part-task training, using their limbs to simulate tourniquet bleeding control or IV insertion. Human use, however, does not create as "safe" a training environment for mistakes as full-body and part-task simulators. Other limitations include availability of participants, lack of tightening tourniquets to full pressure needed to stop bleeding, and not being able to use human participants for all interventions.

A study involving two Active Hemorrhage Simulators (AHS) simulated active bleed to the upper and lower extremities. Both the control and study groups received the typical didactic training. While the control group practiced tourniquet application on each other, the study group used an AHS, which depicted an arm gunshot injury with an active bleed requiring a tourniquet. Then, they were tested seven weeks following their initial training using a different AHS during a timed (unknown to the students) field exercise. This unit depicted a leg gunshot with an active bleed requiring a tourniquet (Mabry, 2005).

The researchers compared the participants' completion times for the field exercise. The results showed a significant difference in the time to stop bleeding, with the AHS group outperforming the control group. The average mean time to stop bleeding in the control group was closer to 4.5 minutes, while the experimental group mean was 3.5 minutes (Mabry, 2005). This one minute difference is meaningful, and in real situation may help save lives and reduce complications (Kragh et al., 2009a; Kragh et al., 2009b; Kragh et al., 2008).

<u>Full-body Simulators</u>

Full-body patient simulators are mannequins that allow students to perform multiple interventions over the many body systems and regions. These simulators include training aids such as Medical Education Technology Incorporated man (METIman), SimMan$^®$ 3G, and S3101 HAL$^®$ (METI, n.d.; Laerdal, n.d.; Gaumards, n.d.). Each of the simulators allow the first responder to treat the entire body of the simulated casualty and perform such interventions as bleeding control and airway maintenance, while being tracked by an After Action Review (AAR) system. An example is shown in Figure 10.

Figure 10: METI Simulator in the Field Environment

<u>Tourniquet Part-Task Trainers</u>

Examples of part-task trainers are the Haptic Medicine (HapMed) arm, leg, and airway trainers by CHI Systems. These devices focus on singular medical procedures, such as arm and leg bleeding control or cricothyroidotomy. The arm tourniquet training system is shown in Figure 11. This part-task trainer allows students and instructors to change the settings for arm circumference, allowing first responders to practice tourniquet application on varying arm sizes. The pressure sensors inside the unit also adjust as the arm circumference setting changes, which is theorized to increase training transfer and realism. This system has two points of simulated injury both above and below the elbow, and the unit is wirelessly controlled with a Personal Digital Assistant (PDA) or similar device. A lighting system illuminates red when simulated bleeding is occurring and green when bleeding has been controlled (Dickinson, demonstration, 2009).

Figure 11: HapMed Tourniquet Arm

A recent study by the Army Research Laboratory (ARL) evaluated three upper extremity hemorrhage part-task trainers with ten participants at the University of Central Florida's College of Medicine (Hackett, Norfleet, & Petttitt, 2011). The three devices included Simulaids arm

tourniquet trainer attached to an upper torso, Metter's arm tourniquet trainer attached to a hinge, and HapMed stand-alone arm tourniquet trainer. The Simulaids trainer yielded the fastest time to cease bleeding with the Metter's system following second. Participants rated the Metter's most favorable followed by the Simulaids. Realism ("realistic pulse, pulse location, skin, and perceived realism") was rated highest again with the Metter's system, with the Simulaids following second (p. 5). The authors mention additional considerations, including cost and ability to train large numbers of students, as well as time-savings, effectiveness, and safety affecting factors. Finally, Hackett et al. make suggestions for an "ideal tourniquet task trainer that includes (2011, p. 6):

- A body connection to serve as an anchor for the arm and to prevent unnatural manipulation of the arm. The whole body also appears to enhance the perception of treating a real human.
- Secure skin attachment on arm that address the pinching and bunching that occurs with plastic and silicon skins.
- Realistic pulse and blood flow.
- Real fluids, not lights.

The above mentioned study addresses the need for improvement in medical simulation to increase realism, reducing the gap between training and reality.

The MATT™ is a lower body bilateral amputee that moves, creating potential difficulty when applying a tourniquet but accurately replicating this potential real-world challenge (Sotomayor & Parsons, 2011). In response to the need for simulation movement characteristics, the MATT™ simulator was originally developed as a Small Business Innovative Research Effort (SBIR) by DNovus, now KGForce, with assistance from Jamie Hyneman of MythBusters. The "Hollywood" influence was desired to increase the system's fidelity (touch, feel, and interaction)

and facilitate inclusion of animatronic movement. MATT is shown in Figure 12, with Jamie Hyneman and Simulation & Training Technology Center's (STTC's) Bill Pike and Dr. Teresita Sotomayor. The MATT™ trainer depicts a lower-torso bilateral amputation, which bleeds from both limbs. Future efforts will incorporate a high-fidelity upper body trainer (also with body injuries, bleeding and animatronic capabilities) to complement the existing lower-body trainer (Sotomayor, personal conversation, 2011).

Figure 12: MATT Simulator

The original creators of the MATT™ have recently delivered a follow-on version of the MATT™ called the Advance MATT. In addition the features of the standard MATT, it includes pressure sensors that detect the force of applied tourniquets and automated performance measurement capabilities. The pressure sensors are theorized to increase the realism by creating an accurate tourniquet application training experience, while the bi-lateral limb movement may create additional difficulty. In this case, when the tourniquet is applied to the MATT™

simulator, bleeding is not ceased unless the tourniquet is within the effective placement and tightness of an actual injury of that nature.

<u>MATT™ Fidelity and Movement Factors</u>

Fidelity can be defined as "the level of realism that a simulation presents to the learner" (Feinstein & Cannon, 2001, p 2). This term encompasses the breakdown of task, physical, functional, physiological, and psychological fidelity. *Medical simulation fidelity* relates to how closely the simulation mimics the real system (Beaubien & Baker, 2004). High-fidelity medical simulation mimics the actual situation as closely as possible by duplicating or replicating the environment, physiological systems, and other realistic characteristics (Liu, Macchiarella, & Vincenzi, 2009).

High-fidelity simulators respond to interventions from students and adapt their behaviors, based upon their physiological models, accordingly. That is, high-fidelity simulators will react to the appropriateness of students' interventions. This dissertation is concerned with the Advanced MATT simulator, which responds to students' bleeding control interventions and ceases bleeding when it senses that a tourniquet has been applied correctly and with sufficient pressure.

Another fidelity feature of the MATT™ and Advanced MATT is movement. While other full-body and part-task simulators may incorporate movement most do not have animatronic movement capabilities. Animatronics are traditionally designed to animate technology such as puppets. It is important to clarify that animatronics incorporate more natural movement

compared to other forms of robotic motion. Thus, for the purposes of this definition, the following definition of animatronics will be used:

> Animatronics comprise the hardware and software components used to create life-like movements in puppets, mannequins, or other figures replicating the motion of natural organisms.

Animatronics are used in the Hollywood film industry in such films as *Jaws* and *Jurassic Park* to bring to life deadly sharks and dinosaurs, respectively. Just as animatronics have brought the abovementioned animals to life, they can be used in the medical arena by simulating limb movement in full-body patient simulators and part-task trainers. The animatronic movement in MATT™ simulates lower limbs that have been traumatically amputated above the knee. This movement aims to create the realism a first responder will face when applying a tourniquet to control lower limb bleeding. This use of animatronics for bleeding control may add to the element of realism for training and evaluation. An individual with a traumatic amputation moving in pain, while conscious, makes tourniquet application a challenge. Practicing tourniquet application with movement may increase training transfer, providing an experience that is taken more seriously. Other high-fidelity features of the MATT™ and Advanced MATT are listed in Table 2.

Table 2: MATT Capabilities

- Feedback on bleeding control
- Repetitive practice
- Training within first responder curriculum
- Difficulty can be modified incorporating movement or non-movement of lower limbs
- Scenarios change the environmental conditions (lab versus battlefield-type scenarios)
- Errors can occur that allow teaching moments for learning
- Individuals or teams learn with hands-on experience
- The bleeding control outcome is clearly defined
- Simulation validity thought to mimic realism of similar complex traumatic amputations

Section Summary

This section described a variety of medical simulation-based training methods including buddy training, part-task trainers, and full-body mannequin simulators. Tourniquet training can be aided by the use of these simulators including the MATT™ and Advanced MATT high-fidelity part-task trainers. Table 3 summarizes key differences among widely used bleeding control simulation-based training. This table compares human use, full-body patient simulators and the MATT™ simulator with regards to trainer properties (i.e. movement, bleeding intervention placement and pressure, cost, durability, instructor and maintenance required, reaction, training preparedness, and Return on Investment (ROI)). Subjective measures were gathered from surveys given to first responders during testing the MATT™. These measures will be discussed more in the methodology and result sections, as all further sections of this study will reference the MATT™ simulator and tourniquet application.

Table 3: Simulation Summary

Trainer Properties	Human Use "buddy"	Status Quo – Full-body Patient Simulator	MATT™ Simulator
Movement	Yes	No	Yes
Models proper bleeding intervention placement to cease bleeding	Yes	Yes	Yes
Model proper pressure to cease bleeding	No	Yes	Yes
Cost	Free	$33K-66K	$40K
Durability	Yes	Partial skin stretching and tearing with excessive use	No skin tearing or stretching to date
Instructor(s)required	1	1	1
Maintenance required	None	Maintenance service contracts	Maintenance service contracts
Emotional Reaction	None	Semi-realistic	Realistic
Participant comments from first responders captured during informal conversations during experimentations	"Not realistic training"	"Realistic but does not combine movement"	"The movement of the MATT provided a real-life experience" "It provides immediate definitive feedback"
ROI	No cost associated, but lower realism	Provides improvement in overall training	Cost similar to status quo similar, provides improvement in overall performance with no negative training

CHAPTER FOUR: METHODOLOGY

A great importance is placed on first responder training, specifically bleeding control. As mentioned, bleeding is the number one cause of death on the battlefield. In many cases, death might be preventable by using a tourniquet. Medical military training gives first responders the opportunity to practice such lifesaving interventions. However, while many medical simulators train bleeding control, most do not add movement. Although, it is hypothesized that movement may initially slow reaction and response time in training settings, their use may enhance operational reaction and response times.

One current gap in our understanding involves the role that movement plays, related to performance and perceived preparedness. Testing objectives for this research therefore include the evaluation of movement (i.e., animatronics) in bleeding control using MATT. Outcome measures evaluate both reaction and treatment time of tourniquet bleeding control including qualitative and quantitative measures.

Reaction Time (Time to Begin Tourniquet Application)

Anecdotal reports reveal that new first responders often struggle with rapid decision-making when confronted by horrific battlefield injuries. These first responders may understand the basic principles of treating these injuries but lack in experience (Cioffi, 1999). More experienced first responders have improved reaction time and can make decisions more rapidly. This experience, and the resulting performance benefits, may be gained by using simulation (Hintz, 2008, Vincent 2009), such as the Advanced MATT simulator used in this study. Vincent

et al. report improved speed and self-efficacy using high-fidelity mannequins to train medical students in a simulated mass casualty event (2009). It is thought that providing greater realism (such as Advanced MATT's movement) might better inoculate them to some negative effects of operational stressors and thereby improve their operational reaction times.

> $H1_a$ – In the <u>immersive scenario</u>, the experimental groups (i.e., those trained on a moving simulator) will have a <u>faster reaction time</u> as compared to those participants who did not receive training on the moving Advanced MATT simulator.

However, it is also acknowledged that applying a tourniquet to a moving limb that is "wounded, wet, slippery, and deformed" may increase the difficulty of that procedure and time of application (Calkins, 2000). Hence, it is further hypothesized:

> $H1_b$ – In the <u>lab-based training</u>, the experimental groups (i.e., those trained on a moving simulator) will have a <u>slower reaction time</u>.

<u>Tourniquet Application Time (Time to Complete Application)</u>

As commented in chapter two, exsanguination during combat occurs over a "usual" time span of 5 to 10 minutes, (Champion et al., 2003) and tourniquets applied faster may help to save lives. The time dependant nature of tourniquet application leads to the next hypothesis:

> $H2_a$ – In the <u>immersive scenario</u>, the experimental groups (i.e., those trained on a moving simulator) will have a <u>faster tourniquet application time</u> when presented with movement.

As with the reaction time, in lab-based training initial training may yield slower tourniquet application times.

> H2$_b$ – In the <u>lab-based training</u>, the experimental groups (i.e., those trained on a moving simulator) will have a <u>slower tourniquet application time</u> when presented with movement.

Subjective Reactions: Perceived Realism

Realism refers to the perception that the training resembles a real situation trainees may encounter (Saus, Johnsen, & Eid, 2010) as well as a representation of the environment it is intended to simulate (Norris, 1986 as cited in Feinstein & Cannon, 2001). It is hypothesized that high realism positively affects training involvement and motivation, and incorporating movement in the Advanced MATT is hypothesized to increase the realism of the injured casualty. A questionnaire was developed that addressed this construct.

> H3 – Participants who complete a tourniquet training <u>immersive scenario</u> on the Advanced MATT simulation with movement will report <u>higher perceived realism scores</u> than participants who complete the training on a static version of the Advanced MATT.

Subjective Reactions: Presence

According to Witmer and Singer, "*presence* is defined as the subjective experience of being in one place or environment, even when one is physically situated in another" (1998, p. 225). For this experiment, *presence*, extrapolated from Chertoff, Schatz, McDaniels, and Bowers (2008), is the feeling of not being able to distinguish between the simulated Advanced MATT event and an actual battlefield event. It is desired to discover if participants are more immersed

when simulation involves movement. A questionnaire was modeled after Witmer and Singer (1998) to help answer the effect of presence in this study.

> H4 – Participants who complete a tourniquet training <u>immersive scenario</u> on the Advanced MATT simulation with movement will report <u>higher presence</u> than participants who complete the training on a static version of the Advanced MATT.

Subjective Reactions: Self-Efficacy

Self-efficacy refers to individuals' judgments of their own competence in regards to specific tasks (Peterson & Arnn, 2005). Bandura describes *self-efficacy* as the "foundation of human agency" (2010, p. 10) because efficacy beliefs play such a central role in individuals' motivation, adaptation, and regulation. Self-efficacy is an important factor influencing personal beliefs regarding operational performance; for instance, medical professions with greater self-efficacy perform better in emergency situations (Vincent, Burgess, Berg, & Connolly, 2009). There is evidence that simulation-based medical training improves students' self-efficacy and downstream operational performance (Nishisaki, Kere, & Nadkarni, 2007). Since self-efficacy beliefs are likely to also affect first responders' performance, a questionnaire was developed to address this construct. Since Nishisaki et al. and Vincent et al. found that higher fidelity simulation led to greater efficacy beliefs, it was hypothesized that the Advanced MATT (with movement) would yield greater self-report efficacy scores.

> H5$_a$ – Participants who complete <u>lab-based</u> tourniquet training on the Advanced MATT simulation with movement will report <u>higher self-efficacy scores</u> than participants who complete the training on a static version of the Advanced MATT.

H5_b – Participants who complete a tourniquet training <u>immersive scenario</u> on the Advanced MATT simulation with movement will report <u>higher self-efficacy scores</u> than participants who complete the training on a static version of the Advanced MATT.

These metrics, measurements, and hypotheses are summarized below in Table 4.

Table 4: Experimental Metrics, Measurement, and Hypotheses

Metric	Reaction Time	Tourniquet Application Time	Reaction Surveys (Affective, utility, Self-efficacy, Perceived Realism, Presence, Perceived difficulty) after scenario one
Measure	Measure of time from crossing the threshold (i.e., body crosses doorway) and placing hands-on the Adv. MATT simulator (i.e., first touch of Adv. MATT)	Measure of time from placing hands-on the dummy (i.e., first touch of Adv. MATT simulator) until bleeding stopped	Likert-style reaction survey with both positively and negatively worded items
Measurement Approach	Two observers with stop-watches	Two observers with stop-watches	Self-report survey after immersive scenario one
Hypotheses	Experimental group will have a slower reaction time in lab-based training and faster reaction time in the immersive scenario.	Experimental group will have a slower tourniquet application time in lab-based training and faster tourniquet application time in the immersive scenario.	Those experiencing movement will rate the episode more highly than groups not receiving movement during the immersive scenario.
Prediction rationale	In initial training, movement will slow reaction times, but this experience should enhance downstream performance.	In initial training, movement will slow tourniquet application times.	Participants' should rate the immersive scenario more positively, based on the increased fidelity due to movement.

<u>Experimental Design</u>

This study uses a 2-X-2 crossover, repeated-measures, mixed-model design. Table 5 displays the four conditions combined with the lab-based training and two scenarios. The

statistics employ various measures of the Analysis of Variance Design (ANOVA), with movement and training scenario factors.

Table 5: Experimental Conditions and Interventions

Condition	X- Pre-Training Lecture	O1	X1 – Lab-based Training	O3 –Scenario1 and Post-Tests	O5 –Scenario2 and Post-Tests
Control (1) Alpha (NM, NM, M)	30 Minute Pre-Training Lecture	Pre-Training Tests	Advanced MATT without movement	Advanced MATT without movement	Advanced MATT with movement
Control (2) Bravo (NM, M, NM)	30 Minute Pre-Training Lecture	Pre-Training Tests	Advanced MATT without movement	Advanced MATT with movement	Advanced MATT without movement
Experimental (3) Charlie (M, NM, M)	30 Minute Pre-Training Lecture	Pre-Training Tests	Advanced MATT with movement	Advanced MATT without movement	Advanced MATT with movement
Experimental (4) Delta (M, M, NM)	30 Minute Pre-Training Lecture	Pre-Training Tests	Advanced MATT with movement	Advanced MATT with movement	Advanced MATT without movement

Note: NM = No Movement and M = Movement. These refer to the order of the experimental trials each group experienced.

Participants

Participants included enlisted military first responders and medical personnel from the Florida Army reserve units in Orlando, Florida, specifically, the 143st Transport in Baldwin Park and Army Reserve Medical Command (ARMEDCOM). Scheduling, training, and testing was coordinated among the previously mention sites to determine population, site availability, and resource requirements.

Participants were distributed with random assignment to the experimental or control groups, as shown in Table 6. Figure 13 illustrates the experimental flow. This experimental design was chosen to minimize experimental bias including potential confounds from students interacting during testing. Special care was taken to ensure that the lab-based and immersive scenarios were identical for all participants, including the exact spatial placement of the Advanced MATT in the testing room, the instructions given to the participants, and the special effects in the immersive environment.

<u>Pre-Training</u>

All participants were given a 30-minute primer on tourniquet application during CUF. This pre-training lecture (Appendix D) was modified from the Army CLS training and is the basis for the standard introductory training material used at the MSTCs. Tourniquet application was demonstrated during the lecture, and presenters reviewed the appropriate steps to stop lower limb bleeding. The steps can be seen in detail in chapter two, under subsection "Two-Handed Tourniquet Application."

<u>Lab training and Immersive Scenarios</u>

Following the lecture, participants practiced tourniquet application on the Advanced MATT during "lab-based training." During this session, normal room lighting was used and no

environmental special effects were employed. Water was pumped through the Advanced MATT in lieu of simulated blood. Water was used at the request of the unit instructors to avoid uniform staining.

Before entering the lab-training as well as the immersive scenarios, all participants were briefed on a fictitious situation involving a casualty event (Appendix E). They were told that their unit was out on convoy when the vehicle in front of them hit an IED. Fire is suppressed, and now they must perform CUF to treat the lower limb bleeding of an injured medic. Once the participant enters the door, the scenario begins. The Advanced MATT was placed 173 inches from the door entrance. Both scenario one and two consisted of lights off, battle sounds, strobe light, and fog all coming from the left side of the Advanced MATT. Table 6 outlines the study timeline in minutes.

Table 6: Experimental Timeline

Experiment Description	Timeline
Introduction and directions	3 minutes
Individual Review Board (IRB) consent form	5 minutes
Demographic information	5 minutes
Pre-training lecture	30 minutes
Random group assignment	5 minutes
Scenario description	5 minutes
Lab-based training	5 minutes
Immersive training scenario 1	5 minutes
Participant reaction survey	5 minutes
Immersive training scenario 2	5 minutes
All groups post-brief (thanks, study groups, questions)	5 minutes

Apparatus and Materials

       Various study components, as seen in Table 7, were used during experimentation. Data were collected on trainees' demographics as well as objective performance metrics (e.g., reaction times). To assess the participants' reactions to the Advanced MATT, a survey using a 7-point Likert scale (Strongly disagree = 1, Disagree = 2, Somewhat Disagree = 3, Neutral = 4, Somewhat Agree = 5, Agree = 6, Strongly Agree = 7) was administered following the first immersive scenario (Appendix F). To minimize testing fatigue, the survey was only administered once (following immersive scenario one) instead of after each trial. This survey consisted of 30 questions over five categories: self-efficacy, perceived realism, presence, perceived difficulty, and utility, with the final question regarding overall training. The final portion of the survey asks the participant what they like most and least about the training.

Table 7: Study Components

Study Components	Descriptions
Independent Variables	Movement component investigated by experimental groups as seen in table 6.
Dependent Variables	Reaction time, tourniquet application time, and reaction survey (perceived realism, self-efficacy, presence) as recorded during each iteration.
Participants	Army Reserve Soldiers at 143rd and ARMEDCOM, chosen randomly.
IRB Approval	Appendix A
Consent Form	Appendix B
Demographic Survey	Appendix C; Information such as age, gender, education, rank, Military Occupation Specialty (MOS), and deployment
Pre-training Lecture	Appendix D; A description of the reduced 30 minute training the participant receives after consent and before testing.
Scenario Description	Appendix E; A description of the scenario before the participant enters the testing environment.
Participant Reaction Survey	Appendix F; This survey is given after the first immersive scenario to capture participant reaction.
Data Collection Form	Appendix G; A form used by the two experimenters to record testing times.
Instructor Reaction Survey	Appendix H; A survey given to instructors for training feedback.

Reaction-Time and Tourniquet Application Time

Experimental times were monitored by two experimenters to increase measurement accuracy. *Reaction time* began when a participant crossed the door threshold and ended at first touch on the Advanced MATT. *Tourniquet application time* (*left leg* and *right leg*) represents the time between placing hands on the Advanced MATT and bleeding cessation of that limb. This time was divided by the left and right legs. *Left and right total tourniquet application* comprises

the total time to apply tourniquets to both legs. *Overall total exercise time* is the overall total time that a participant took to complete the exercise (reaction time plus tourniquet application time for both legs). Notations have been made if multiple tourniquets were applied to a leg, in cases where bleeding was not completely stopped with a single tourniquet or if a tourniquet broke. The times recorded by the two experimenters were averaged for each of these variables (see Appendix G for the experimenter data form).

An internal pilot test was conducted prior to reserve site testing. This test helped the two timers get accustomed to recording the reaction and tourniquet application times. Pilot testing also identified the time needed for resetting the Advanced MATT simulation, as well as other logistical considerations, and helped establish expectations for the experimental timeline.

CHAPTER FIVE: RESULTS

This chapter discusses the results of the Advanced MATT experimentation. Testing details and logistics are first described followed by the data analyses. The results are broken down into the overall training effect of the Advanced MATT, followed by a discussion of the *a prior* hypotheses. The hypotheses are divided into two sections. The first involves the analysis of reaction and tourniquet times, that is hypotheses one through two. The second section describes the results for hypotheses three through five. The last portion of the results section focuses on participant comments as well as a discussion of the reported findings.

Data Collection

The Advanced MATT lower limb simulator experiment was conducted at the 143rd and ARMEDCOM reserve centers between 6 August and 20 August 2011. Testing was conducted over one full training day at each of the sites. A total of 41 reserve Soldiers participated in the study. Participants were separated into morning and afternoon groups, allowing the reserve Soldiers to complete other pre-deployment requirements during testing downtime.

Each experimental trial was completed by a single participant at a time. Trials lasted an average of 3–7 minutes, beginning when a participant entered the room and ending once a tourniquet was successfully applied to each leg. Left and right (combined) total tourniquet application time was limited to five minutes. After five minutes had been reached, each participant was thanked for his/her participation and asked to leave, regardless of whether or not

he/she successfully completed tourniquet application. Successful completion was defined as total cessation of blood flow (i.e., no remaining trickle of blood flow). Five minutes was chosen as the maximum time limit because, as mentioned previously, exsanguination during combat occurs in 5 to 10 minutes (Champion et al., 2003) and may be as little as 2 minutes in severe cases (Wenke, Walters, Greydanus, Pusateri, & Convertino, 2005).

Participants

All forty-one participants were evenly distributed over four random groups, and each group completed three trials. Trials were as follows: zero (lab-training), trial one (immersive scenario one), and trial two (immersive scenario two). The groups (Table 8) were as follows: control Group 1 (No Movement, No Movement, Movement or NM, NM, M), control Group 2 (NM, M, NM), experimental Group 3 (M, NM, M), and experimental Group 4 (M, M, NM). Participant demographics are displayed in Table 9 and Table 10. Demographic information is shown in Figures 13 – 21.

Table 8: Group Distribution

Groups	Movement Component	Number of Participants Per Group
Control Group One	NM, NM, M	13
Control Group Two	NM, M, NM	8
Experimental Group Three	M, NM, M	10
Experimental Group Four	M, M, NM	10

Table 9: Sample Population Demographic Description

Demographic Description	Sample Participants
Age	20 to 52 years
Gender	32 males and 9 females
Education	High school to post-graduate
Years' experience	2 to 30 years
Rank	Private to Major
MOS	8 Medics, 8 CLS, 8 other medical (i.e., nurse, PA, medical assistant), 17 non-medical

Table 10: Sample Population Demographic Statistics

	Group	n	M	SD
Age	Control Group One	13	33.62	11.25
	Control Group Two	8	27.88	5.03
	Experimental Group Three	10	32.40	11.35
	Experimental Group Four	10	34.20	10.71
Gender	Control Group One	13	1.00 (male)	.00
	Control Group Two	8	1.38 (male)	.52
	Experimental Group Three	10	1.30(male)	.48
	Experimental Group Four	10	1.30 (male)	.48
Education	Control Group One	13	2.15 (associates)	1.34
	Control Group Two	8	1.63 (associates)	.74
	Experimental Group Three	10	3.00 (bachelors)	1.56
	Experimental Group Four	10	2.60 (bachelors)	1.43

	Group	n	M	SD
Years Served	Control Group One	13	6.23	5.56
	Control Group Two	8	6.63	3.62
	Experimental Group Three	10	8.40	5.10
	Experimental Group Four	10	8.10	8.36
Rank	Control Group One	13	3.38 (specialist)	1.19
	Control Group Two	8	3.88 (sergeant)	1.64
	Experimental Group Three	10	4.00 (sergeant)	1.70
	Experimental Group Four	10	4.00 (sergeant)	1.94
Medical MOS	Control Group One	13	.92 (CLS)	1.19
	Control Group Two	8	1.63 (Medic)	1.19
	Experimental Group Three	10	1.30 (CLS)	1.16
	Experimental Group Four	10	1.00 (CLS)	1.25
Deployed Experience	Control Group One	13	1.54 (not deployed)	.52
	Control Group Two	8	1.37 (deployed)	.52
	Experimental Group Three	10	1.30 (not deployed)	.48
	Experimental Group Four	10	1.50 (deployed)	.53
Combat Tourniquet Application	Control Group One	13	1.85 (combat tourniquet not applied)	.38
	Control Group Two	8	1.87 (combat tourniquet not applied)	.35
	Experimental Group Three	10	1.90 (combat tourniquet not applied)	.32
	Experimental Group Four	10	1.80 (combat tourniquet not applied)	.42
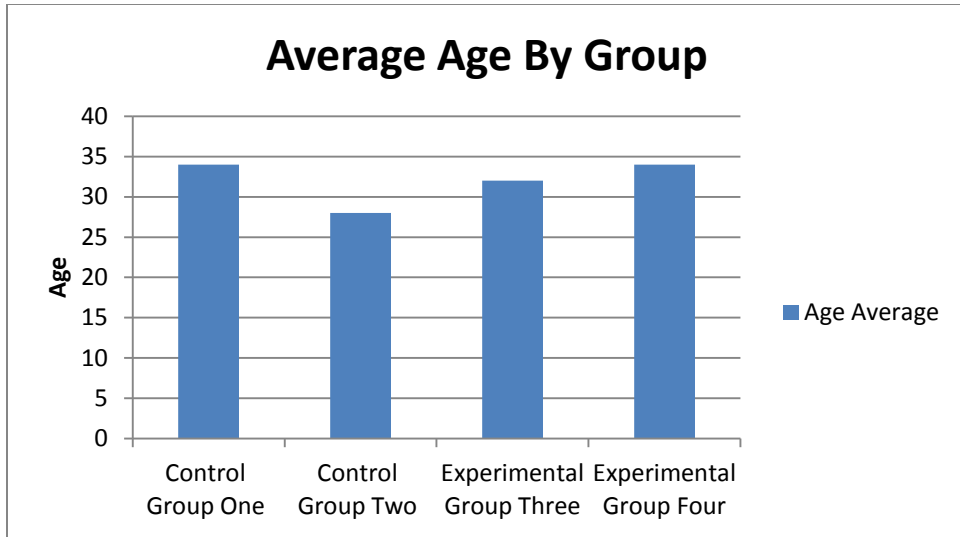
Figure 13: Average Age by Group
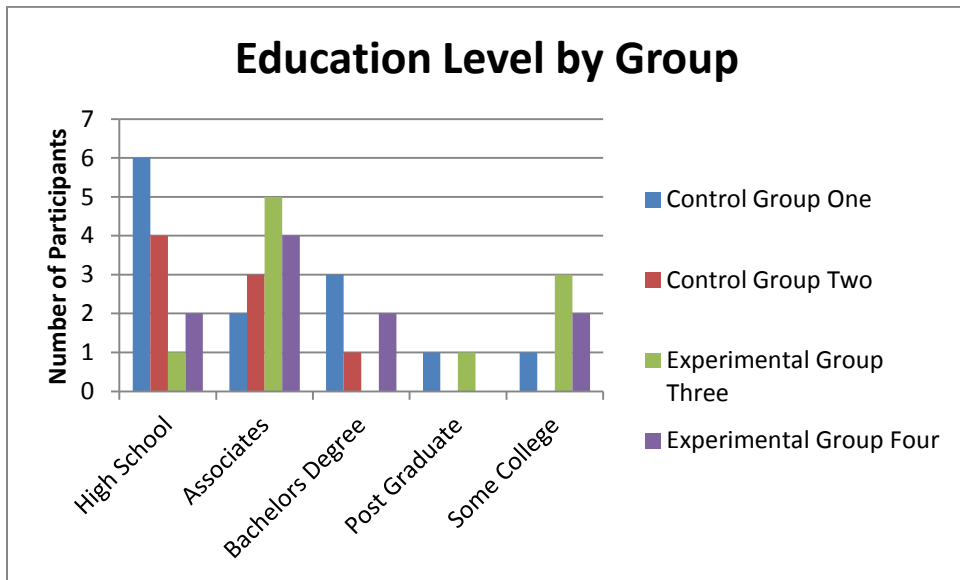
Figure 14: Education Level by Group
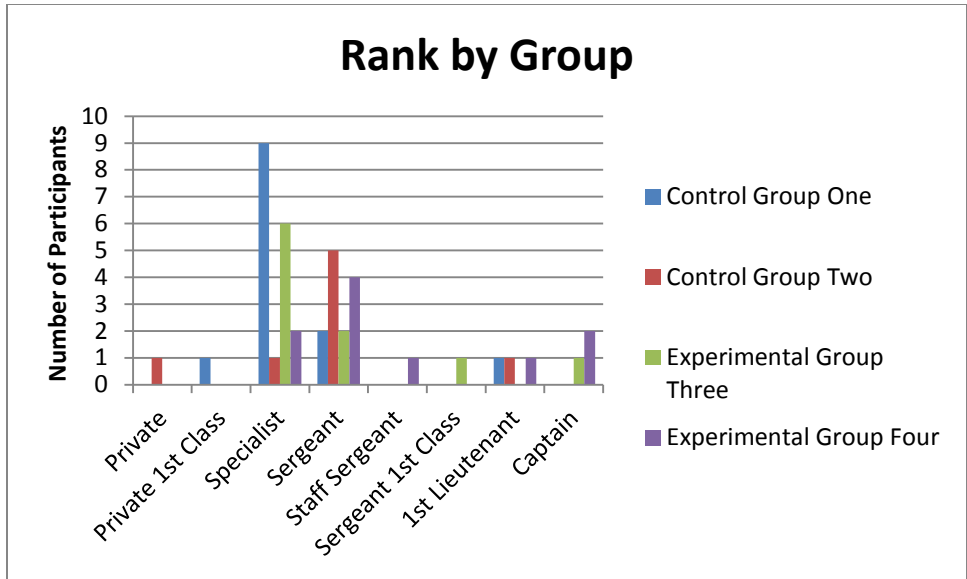
Figure 15: Rank by Group
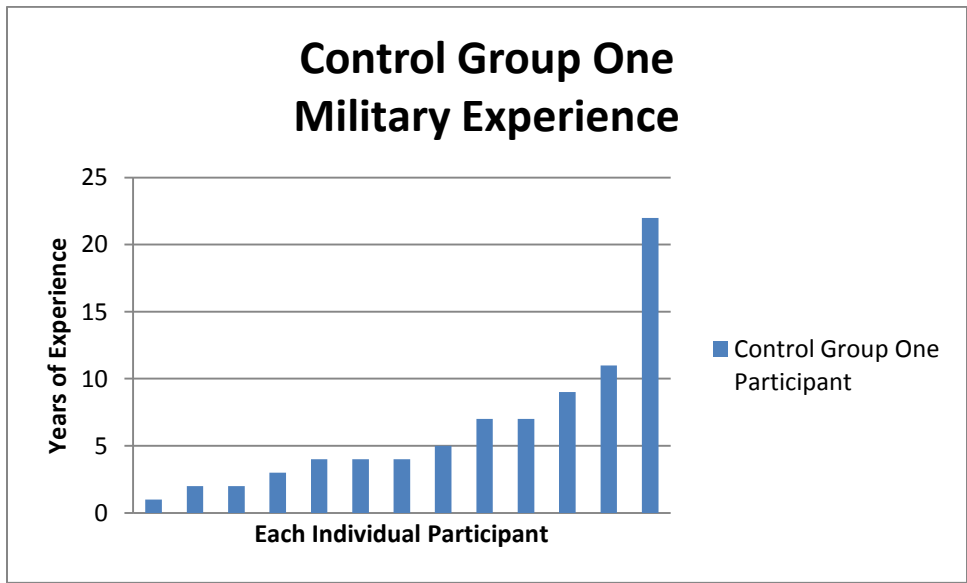
Figure 16: Military Years of Experience for Control Group One
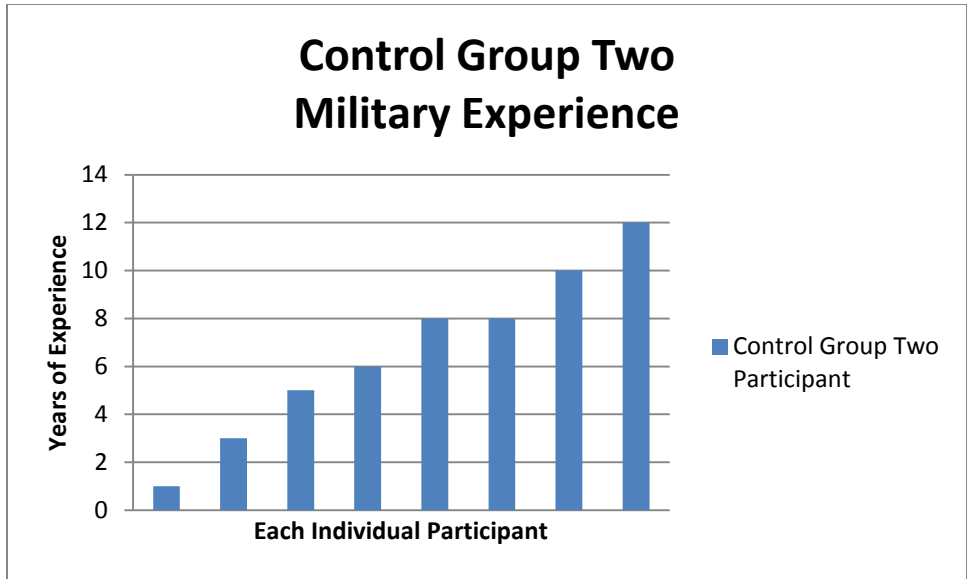
Figure 17: Military Years of Experience for Control Group Two
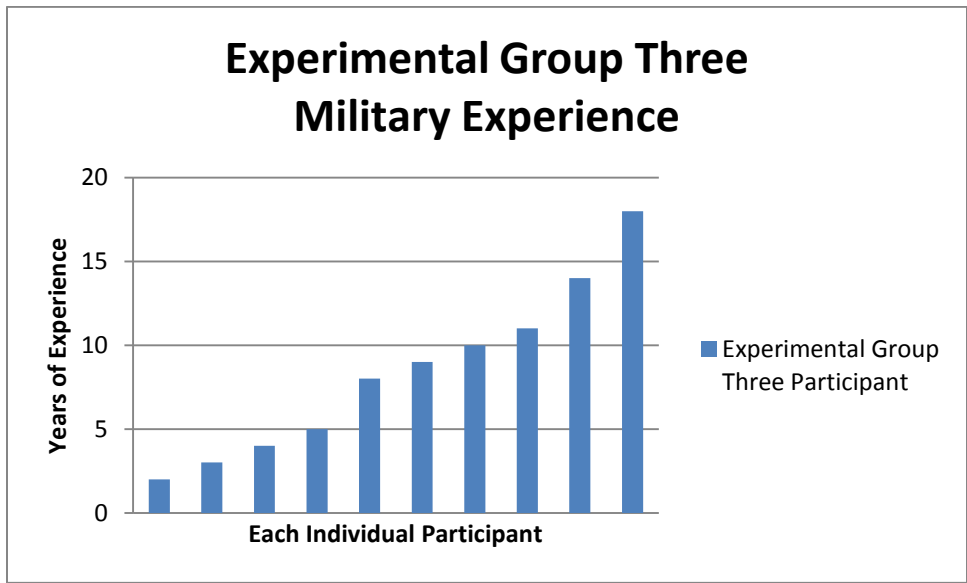
Figure 18: Military Years of Experience for Experimental Group Three
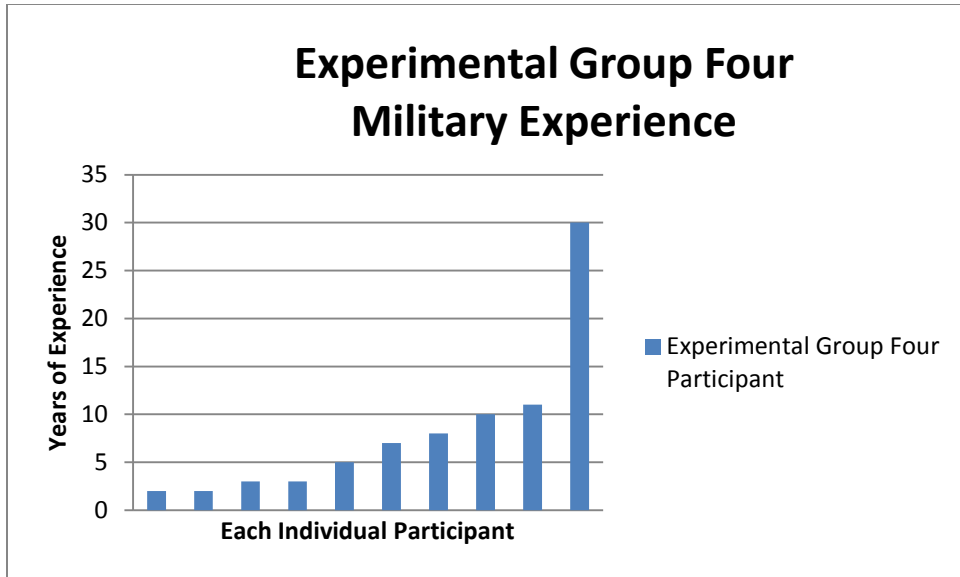
Figure 19: Military Years of Experience for Experimental Group Four
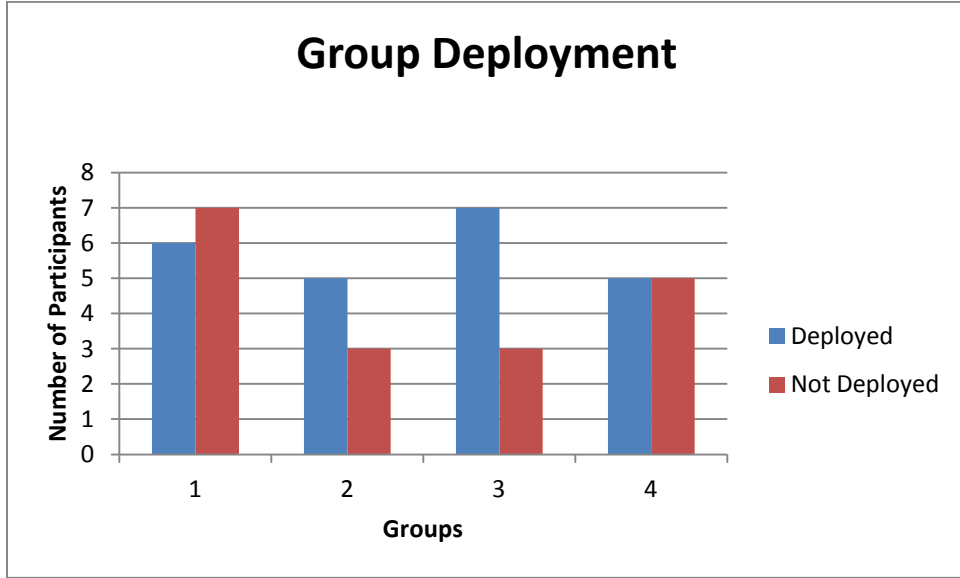
Figure 20: Group Combat Deployment Experience
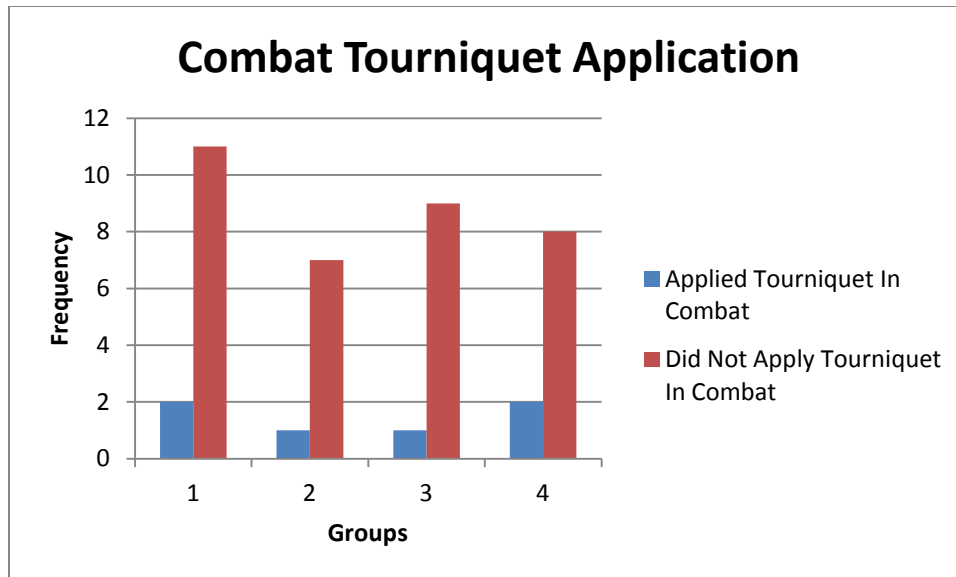
Figure 21: Combat Tourniquet Application Experience

Covariates

The data were examined for potentially meaningful covariates. The frequency of possible covariates across each of the groups was examined. The potential covariates included age, gender, rank, education level, military years of experience (active and reserve duty), MOS, previous combat deployments, and application of a tourniquet while in combat. A one-way multivariate analysis of variance (MANOVA) was performed to investigate the covariates. The dependent variables were age, gender, rank, education level, military years of experience, previous combat deployments, and application of a tourniquet in combat. The independent variable was group number. The analysis did not reveal meaningful differences, indicating that participants' characteristics were sufficiently balanced across the groups, age $F(1, 40) = .683$, p

= .568, gender $F(1, 40) = .1.927, p = .142$, education $F(1, 40) = .1.785, p = .167$, military years of service $F(1, 40) = .344, p = .793$, rank $F(1, 40) = .395, p = .757$, MOS $F(1, 40) = .678, p = .571$, previous combat deployments $F(1, 40) = .686, p = .686$, application of a tourniquet in combat $F(1, 40) = .133, p = .940$.

Pre-training Lecture

During the pre-training lecture (Appendix D), participants received both verbal and visual instructions on tourniquet application. Care was placed to explain the steps for lower limb tourniquet application in detail. These steps were explained multiple times with emphasis on placing the self-adhering band strap through both sides of the friction adapter buckle. Previous experience, as well as doctrine (Parsons, 2010), shows that both friction adapter buckles are needed to control lower limb bleeding, while only one friction adapter buckle may stop upper limb bleeding. A correctly applied lower limb tourniquet is shown in Figure 22. Figures 23 and 24 illustrate incorrectly applied tourniquets. Figure 23 did not use the second friction adaptor belt while Figure 24 did not apply the tourniquet tight enough, as shown by the self-adhering-band strap that is twisted and lower than the friction adapter buckle.

Figure 22: Correct Application of Tourniquet

Figure 23: Incorrect Use of Friction Adapter Buckle

Figure 24: Incorrect Tourniquet Self-Adhering Band Not Pulled Tight Enough

Each site (143rd and ARMEDCOM) received identical room set-up and testing procedures. The Advanced MATT was placed 173 inches from the door on a tarp to gather simulated blood (water), as seen in Figure 25. Simulated blood mix was not used, per instructor request, to reduce uniform staining. Sound, fog, and strobe lighting were placed approximately three feet from the Advanced MATT's left side.

Figure 25: Advanced MATT Logistic Room Set-Up

Following the consent and thirty minute pre-training lecture, participants were randomly assigned to one of the four previously described groups. The participants were told that their mission was the same for each of the three trials (lab, scenario one, and scenario two), although the lab-training would be different than the immersive scenarios. Due to the desired avoidance of Post-Traumatic Stress Disorder (PTSD), participants were told that the immersive scenario

contained battlefield effects: darkness, battle sounds, strobe-light, and fog (Figure 26). Only one participant was not able to tolerate the strobe-lighting due to previous injury, and he completed the scenario without the strobe light. Each group received the same scenario instructions (Appendix E) as seen below.

- Your unit is on convoy

- The vehicle in front of you just rolled over from an IED

- Fire is suppressed

- Your job as part of CUF is to treat the lower limb bleeding of your injured medic

- Once you enter the door your scenario begins

Figure 26: Immersive Scenario Tourniquet Application

The participants were called into the experimental room one by one, each accomplishing the lab-training, followed by immersive scenario one, the reaction survey, and finishing with immersive scenario two. Each of the groups was kept together throughout the day to eliminate discussion across cohorts.

Advanced MATT experimental reset consisted of refilling the self-contained blood canister and resetting both tourniquets to the identical position for each participant. Tourniquets were place in each of the pant cargo pockets of the Advanced MATT, which is a common practice among Soldiers. Finally, wet pads were replaced and surrounding areas wiped down to avoid slippage.

Explanation of Reaction and Tourniquet Application Times

Because of the complex dynamics of the Advanced MATT, testing measured five relevant times (measured in seconds). These times were recorded by two timers and averages were used for the statistical computations. The observed time measures are described in Table 11 and explained below.

Reaction time describes the time elapsed between a participant crossing the door threshold and ending after he/she placed hands on Advanced MATT. Tourniquet application times are broken down for each leg as well as pooled for an average overall time to stop bleeding to both legs. Finally, total time records the entire exercise from reaction time to tourniquet application to both legs.

Table 11: Measurement Variables

Measurement ID	Description
Reaction time	Time to cross door threshold, lay hands on MATT
Left tourniquet time	Time to apply left leg tourniquet
Right tourniquet time	Time to apply right leg tourniquet
Left and right leg total time	Total time for left and right leg tourniquets
Total exercise time	Total time reaction to completion

Participant Survey Evaluation

The participant survey consisted of 30 questions divided among six subscales (utility, perceived realism, perceived difficulty, presence, and self-efficacy) and an overall impression question. Statements alternated between positively and negatively worded items. The negatively worded statements were re-coded before analysis. Survey responses were in a 7-point Likert scale with an additional two questions asking overall most and least liked. The participant survey can be seen in its entirety in Appendix F.

Results

Experimental results are categorized by participant performance times (measured in seconds) and subjective reactions (measured by survey response). These results were evaluated using $\alpha = .05$. Table 12 reiterates the group divisions and experimental design.

Table 12: Movement Comparison between Lab-based, Scenario 1, and Scenario 2 Trials

Condition	Lab-based Training	Scenario 1	Scenario2
Control (1) Alpha	MATT without movement (NM)	MATT without movement (NM)	MATT with movement(M)
Control (2) Bravo	MATT without movement (NM)	MATT with movement(M)	MATT without movement (NM)
Experimental (1) Charlie	MATT with movement (M)	MATT without movement (NM)	MATT with movement (M)
Experimental (2) Delta	MATT with movement (M)	MATT with movement (M)	MATT without movement (NM)

Advanced MATT Training Effect

Before the hypothesis-specific results were analyzed, the impact of training on the Advanced MATT (regardless of whether movement was activated or not) was assessed. In other words, an analysis was conducted to determine whether participants' performance improved over the three trials. A repeated-measure ANOVA was conducted for the three trials (lab, scenario 1, and scenario 2). The independent variable was the trial number. The dependent variables included reaction time and left leg tourniquet application time, right leg tourniquet application time, and left and right tourniquet application time.

The analysis revealed a significant effect for trial on reaction time, $F(1, 40) = 6.73$, $p <$ **.01**, left leg tourniquet time, $F(1, 40) = 7.42$, $p < .01$, left and right leg total tourniquet time, $F(1, 40) = 4.18$, $p = .02$, and total exercise time, $F(1, 40) = 4.05$, $p = .02$. This indicates that the experimental intervention (i.e., tourniquet practice on the Advanced MATT) improved

participants' performance regardless of the group or if movement was received. Table 13 displays the mean times in seconds seen across the lab-training to scenarios.

Table 13: Repeated Measures Overall Training Effect Descriptive Statistics for Reaction, Left Tourniquet, Right Tourniquet, Left and Right Tourniquet, and Total Exercise Time across Lab, Scenario One, and Scenario Two

Dependent Variables	N	Lab (Trial Zero)		Scenario One		Scenario Two		F	p Value	Partial Eta Squared
		Mean	SD	Mean	SD	Mean	SD			
Overall Reaction Time	41	5.6829	3.01197	4.4146	1.58075	4.0049	1.14825	6.73	**.003**	.257
Overall Left Tourniquet Application	41	59.67	30.79	100.22	60.56	74.78	46.79	7.42	**.002**	.276
Overall Right Total Tourniquet Application	41	85.80	72.35	97.07	60.09	79.98	54.11	1.26	.295	.061
Overall Left and Right Tourniquet Application	41	147.90	86.62	199.51	95.49	164.63	80.72	4.18	**.023**	.177
Overall Total Time	41	153.56	86.50	203.88	95.91	168.63	80.78	4.05	**.025**	.172

Except for reaction time, the general trend was an increase in time (worse performance) from lab-training to scenario one, followed by a decrease in time (better performance) in scenario two. This trend was expected as the lab-training contained lights on and scenario one contained darkness and battlefield effects. Figure 27 shows reaction, left and right tourniquet times, and total training times graphically, with the times broken down into lab-training, scenario one, and scenario two. As seen in Table 13, a significant training effect did occur as times improved across the trials.
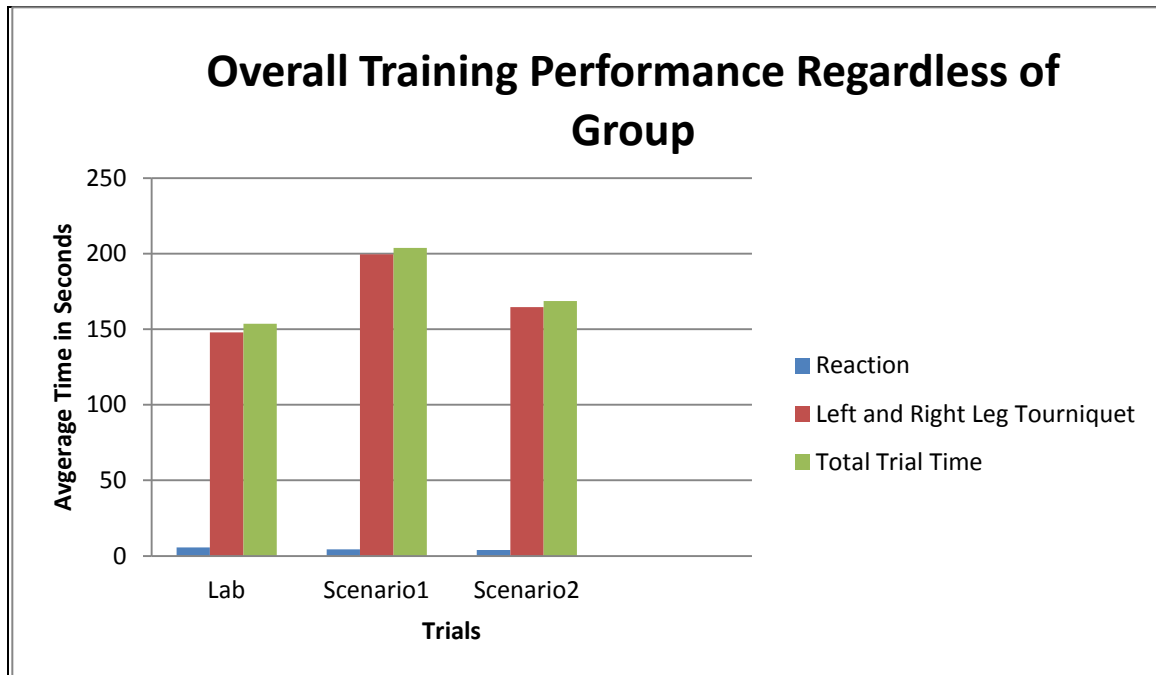
Figure 27: Comparison of Mean Times – Reaction, Left and Right Leg Total Tourniquet and Total Trial Times across Lab, Scenario1, and Scenario2

Since the repeated-measure ANOVA showed significant differences for four of the variables, pairwise comparisons were conducted to identify differences between the specific trials. Results are shown in Tables 14 through 17. For reaction time, all three trials were different from one another. The difference in reaction times between these scenario one and two trended towards significance but failed to reach it ($p = .052$). Pairwise comparison for reaction time revealed differences, $F(1, 40) = 6.73$, $p < .01$. Left leg tourniquet application time revealed differences in the lab training and scenario one and scenario one and scenario two trials, $F(1, 40) = 6.73$, $p = .01$. Left and right leg total tourniquet application also revealed differences in the lab training and scenario one as well as scenario one and scenario two trials, $F(1, 40) = 4.18$, $p < .01$. This same trend was seen in the results for total exercise time, $F(1, 40) = 4.05$, $p < .01$.

Table 14: Repeated Measures Pairwise Comparison across Reaction Time and Trials

Reaction Time		p Value	F Statistic	Partial Eta Squared
lab zero	scenario one	**.005**	6.73	.257
	scenario two	**.001**		
scenario one	lab zero	**.005**		
	scenario two	**.052**		
scenario two	lab zero	**.001**		
	scenario one	**.052**		

Table 15: Repeated Measures Pairwise Comparison across Left Tourniquet Time and Trials

Left Leg Time		p Value	F Statistic	Partial Eta Squared
lab zero	scenario one	**.000**	7.42	.276
	scenario two	.092		
scenario one	lab zero	**.000**		
	scenario two	**.011**		
scenario two	lab zero	.092		
	scenario one	**.011**		

Table 16: Repeated Measures Pairwise Comparison across Left and Right Total Tourniquet Time and Trials

Left and Right Total Times		p Value	F Statistic	Partial Eta Squared
lab zero	scenario one	**.008**	4.18	.177
	scenario two	.307		
scenario one	lab zero	**.008**		
	scenario two	**.029**		
scenario two	lab zero	.307		
	scenario one	**.029**		

Table 17: Repeated Measures Pairwise Comparison across Total Exercise Times and Trials

Total Exercise Time		p Value	F Statistic	Partial Eta Squared
lab zero	scenario one	**.009**	4.05	.172
	scenario two	.354		
scenario one	lab zero	**.009**		
	scenario two	**.028**		
scenario two	lab zero	.354		
	scenario one	**.028**		

Advanced MATT Performance Times

This section describes the detailed analyses related to the hypotheses discussed in chapter four. The results are discussed individually for hypotheses one_a and one_b, (reaction times), two_a and two_b, (tourniquet application times), and three, four, $five_a$, and $five_b$ (participant reactions). Table 17 helps clarify which of the four groups experienced movement (or no movement) during the various experimental trials.

Table 18: Summary of Group Intervention

Condition	Group	Lab 0	Scenario 1	Scenario 2
Control	Alpha (1)	NM	NM	M
	Bravo (2)	NM	M	NM
Experimental	Charlie (3)	M	NM	M
	Delta (4)	M	M	NM

Hypothesis One$_a$: Immersive Scenario Reaction Time

H1$_a$ – In the immersive scenario, the experimental groups i.e., those trained on a moving simulator will have a faster reaction time as compared to those participants who did not receive training on the moving MATT simulator.

For this hypothesis, three analyses were conducted. The first analysis compared the reaction times in immersive scenario one for Group 1 versus Group 3 (i.e., the two cohorts that experienced the static Advanced MATT during immersive scenario one), and it compared Group 2 versus Group 4 (i.e., the two cohorts that experienced the moving Advanced MATT in the first immersive scenario). The second analysis compared reaction times in immersive scenario two for Groups 1 versus 3 (experienced movement) and Groups 2 versus 4 (no movement). Finally, in third analysis the reaction time scores for the two control groups were pooled together and their scores across both immersive scenarios were also combined; similarly, reaction time scores were pooled for the experimental groups and across the two immersive scenario trials. Then the consolidated reaction time scores for the control cohorts (Groups 1 and 2 across both scenarios) were compared to the consolidated reaction time scores for the experimental cohorts (Groups 3 and 4 across both scenarios). By doing this the downstream effects of lab-based training (i.e., with or without the animatronics in the lab-based practice) were evaluated.

In scenario one, experimental Group 3 (M, NM) had better reaction times ($M = 4.10$, $SD = 1.10$) than did control Group 1 (NM, NM) ($M = 4.85$, $SD = 1.13$), $F(1,21) = 1.13$, $p = .300$. Experimental Group 4 (M, M) had better reaction times ($M = 4.00$, $SD = 1.33$) than did control Group 2 (NM, M) ($M = 4.63$, $SD = 1.69$), $F(1,16) = .77$, $p = .39$ (Table 19). Although not statistically significant, the better (faster) reaction times demonstrated by the experimental groups (3 and 4) may indicate that an effect from the lab-training with movement; this is described in more detail in the Discussion section.

Table 19: Scenario One – Reaction Time Comparison between Groups 1 vs. 3 (No Movement) and 2 vs. 4 (Movement)

Scenario 1	Group 1 vs. 3 and 2 vs. 4	n	Mean	SD	*F* Statistic	One-Tailed *p* Value	Partial Eta Squared
ReactionScen1 Groups 1 and 3 Received NM	Group One (NM, NM)	13	4.85	1.99	1.13	.15	.05
	Group Three (M, NM)	10	4.10	1.10			
ReactionScen1 Groups 2 and 4 Received M	Group Two (NM, M)	8	4.63	1.69	.77	.196	.05
	Group Four (M, M)	10	4.00	1.33			

In scenario two, the reaction time of Group 3 (M, NM, M) was better ($M = 3.75$, $SD = .99$) than Group 1 (NM, NM, M) ($M = 4.25$, $SD = 1.42$), $F(1,21) = 1.13$, $p = .350$. Group 4 (M, M, NM) had better reaction time ($M = 4.10$, $SD = 1.10$) than did Group 2 (NM, M, NM) ($M = 3.77$, $SD = .84$), $F(1,16) = .80$, $p = .384$ (Table 20). Although not significant, the better (faster) reaction times demonstrated by the experimental groups (3 and 4) may indicate an effect of experiencing movement in the lab-training.

Table 20: Scenario Two – Reaction Time Comparison between Groups 1 vs. 3 (Movement) and 2 vs. 4 (No Movement)

Scenario 2	Group 1 vs. 3 and 2 vs. 4	n	Mean	SD	F Statistic	One-tailed p Value	Partial Eta Squared
ReactionScen2 Groups 1 and 3 Received M	Group One (NM, NM, M)	13	4.25	1.42	.91	.153	.04
	Group Three (M, NM,M)	10	3.75	.99			
ReactionScen2 Groups 2 and 4 Received NM	Group Two (NM, M, NM)	8	4.21	1.26	.80	.192	.05
	Group Four (M, M, NM)	10	3.77	.84			

For the third analysis, the combined control groups' reaction time scores were pooled across the two immersive scenarios and compared to the two experimental groups' reaction time scores, which were also pooled across the two immersive scenarios. The experimental groups (3 and 4) demonstrated better reaction times ($M = 3.90$, $SD = 1.61$) than did the control groups (1 and 2), ($M = 4.50$, $SD = 1.05$), $F(1,80) = 3.90$, **one tailed p = .026** (Table 21, Figure 28). These results suggest that the experimental groups (who trained with a moving Advanced MATT during the lab-based practice) performed better on the immersive scenarios, overall, than did the control groups (who trained on a static Advanced MATT during practice). These results are discussed in more detail in the next section.

Table 21: Experimental vs. Control Group Reaction during Immersive Scenarios

Reaction Type	Group Type	n	Mean	SD	*F* Statistic	One-tailed *p* Value	Partial Eta Squared
Reaction Immersive Scenario	Control (Groups 1 and 2) No Mvt Trained	42	4.50	1.61	3.90	**.026**	.05
	Experimental Mvt (Groups 3 and 4) Trained	40	3.90	1.05			
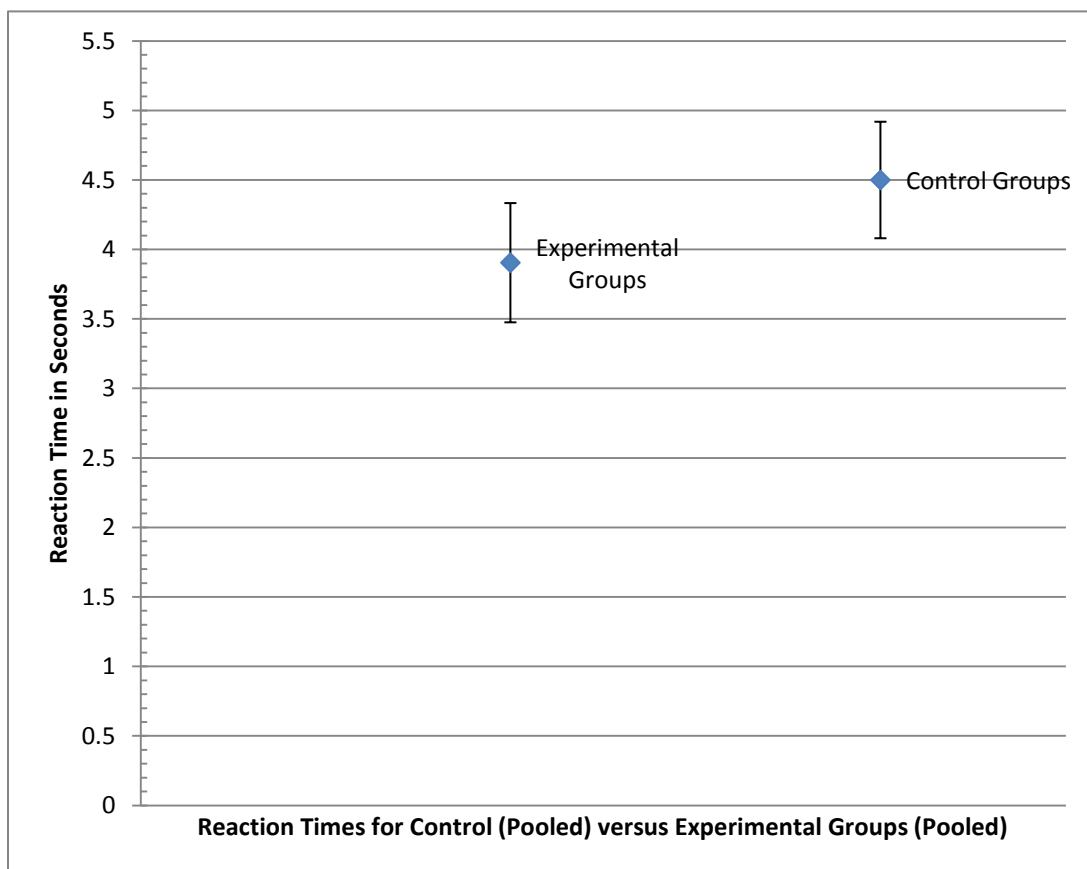
Figure 28: Experimental Versus Control Group Immersive Scenarios Reaction Time

Hypothesis One$_b$: Analysis and Results – Lab-based Reaction Time

H1$_b$ – In the <u>lab-based training</u>, the experimental groups i.e., those who were trained on a moving simulator will have a <u>slower reaction time</u>.

For this hypothesis, one analysis was conducted. This analysis compared the reaction times in the lab-based training for Group 1 and 2 (i.e., the two cohorts that experienced the static Advanced MATT during lab-training), and it compared Group 3 and 4 (i.e., the two cohorts that experienced the moving Advanced MATT in the lab-training). This analysis evaluated the downstream effects of the lab-based training (i.e., with or without the animatronics in the lab-based practice) on performance in the immersive scenario.

The experimental groups (3 and 4) reported better reaction times (M = 5.40, SD = 2.85) than did the control groups (1 and 2), (M = 5.98, SD = 3.20), $F(1,39) = .34$, $p = .56$, (Table 22). Although not statistically significant, the better (faster) reaction times demonstrated by the experimental groups (3 and 4) reflect an effect of lab-training with movement; this is explained in more detail in the Discussion section.

Table 22: Experimental Vs. Control Group Reaction during Lab-Training

Reaction Type	Group Type	n	Mean	SD	F Statistic	One-tailed P Value	Partial Eta Squared
Reaction Lab Training	Control (Groups 1 and 2) No Mvt Training	21	5.95	3.20	.34	.253	.01
	Experimental (Groups 3 and 4) Mvt Training	20	5.40	2.85			

Hypothesis Two$_a$: Analysis and Results – Immersive Scenario Tourniquet Application Time

> H2$_a$ – In the <u>immersive scenario</u>, the experimental groups i.e., those who were trained on a moving simulator will have a <u>faster tourniquet application time</u> when presented to movement.

For this hypothesis, three analyses were conducted. The first analysis compared the tourniquet application times in immersive scenario one for Group 1 versus Group 3 (i.e., the two cohorts that experienced the static Advanced MATT during immersive scenario one), and it compared Group 2 versus Group 4 (i.e., the two cohorts that experienced the moving Advanced MATT in the first immersive scenario). The second analysis compared tourniquet application times in immersive scenario two for Groups 1 versus 3 (experienced movement) and Groups 2 versus 4 (no movement). Finally, in third analysis the tourniquet application time scores for the two control groups were pooled together and their scores across both immersive scenarios were also combined; similarly, tourniquet application time scores were pooled for the experimental groups and across the two immersive scenario trials. Then the consolidated tourniquet application time scores for the control cohorts (Groups 1 and 2 across both scenarios) were compared to the consolidated tourniquet application time scores for the experimental cohorts (Groups 3 and 4 across both scenarios). By doing this the downstream effects of lab-based training (i.e., with or without the animatronics in the lab-based practice) were evaluated.

In scenario one, experimental Group 3 had better reaction times for left and right leg total tourniquet time ($M = 203.50$, $SD = 86.78$) than did control Group 1 ($M = 208.31$, $SD = 107.06$), $F(1,16) = .01$, $p = .909$. Experimental Group 4 had better reaction for the left and right leg total tourniquet time ($M = 190.80$, $SD = 98.60$) than did control Group 2 ($M = 191.12$, $SD = 99.61$),

$F(1,16) = 3.21$, one tailed **_p_ = .044** (Table 23). These significant results may be reflective of movement training and are discussed in more detail in the Discussion section.

Table 23: Scenario One – Tourniquet Application Time Comparison between Groups 1 vs. 3 (No Movement) and 2 vs. 4 (Movement)

Tourniquet Type	Group Type	n	Mean	SD	_F_ Statistic	One-tailed _P_ Value	Partial Eta Squared
Left Leg Tourniquet Scen1 Groups 1 and 3	Group One (NM, NM)	13	99.31	60.37	.07	.400	.003
	Group Three (M, NM)	10	106.00	63.37			
Right Leg Tourniquet Scen1 Groups 1 and 3	Group One (NM, NM)	13	102.38	64.30	.03	.239	.002
	Group Three (M, NM)	10	97.70	56.29			
Left and Right Leg Total Tourniquet Scen1 Groups 1 and 3	Group One (NM, NM)	13	208.31	107.06	.01	.455	.001
	Group Three (M, NM)	10	203.50	86.78			
Left Leg Tourniquet Scen1 Groups 2 and 4	Group Two (NM, M,)	8	91.37	54.76	2.67	.056	.113
	Group Four (M, M)	10	102.70	70.54			
Right Leg Tourniquet Scen1 Groups 2 and 4	Group Two (NM, M)	8	99.62	68.23	.73	.201	.034
	Group Four (M, M)	10	87.50	59.97			
Left and Right Leg Total Tourniquet Scen1 Groups 2 and 4	Group Two (NM, M)	8	191.12	99.61	3.21	**.044**	.133
	Group Four (M, M)	10	190.80	98.60			

In scenario two, for the left and right leg total tourniquet application time, Group 3 (M, NM, M) reported better tourniquet application time (M = 147.80, SD = 74.94) than did Group 1 (NM, NM, M) (M = 207.77, SD = 82.88, $F(1,21) = .00$, _p_ = .995. Group 4 (M, M, NM) also

reported better tourniquet application time (M = 150.00, SD = 79.88) than did Group 2 (NM, M, NM) (M = 133.87, SD = 69.17), $F(1,16) = .20$, $p = .658$. Table 24 displays the complete statistics. Although not significant, the better (faster) left and right leg total tourniquet application times demonstrated by the experimental groups (3 and 4) may indicate an effect of experiencing movement in the lab-training.

Table 24: Scenario Two – Tourniquet Application Time Comparison between Groups 1 vs. 3 (Movement) and 2 vs. 4 (No Movement)

Tourniquet Type	Group Type	n	Mean	SD	*F* Statistic	One-tailed *P* Value	Partial Eta Squared
Left Leg Tourniquet Scen2 Groups 1 and 3	Group One (NM, NM, M)	13	104.23	61.53	.14	.356	.009
	Group Three (M, NM, M)	10	67.90	38.51			
Right Leg Tourniquet Scen2 Groups 1 and 3	Group One (NM, NM, M)	13	83.92	41.83	.16	.394	.010
	Group Three (M, NM, M)	10	70.20	32.76			
Left and Right Leg Total Tourniquet Scen2 Groups 1 and 3	Group One (NM, NM, M)	13	207.77	82.88	.00	.498	.000
	Group Three (M, NM, M)	10	147.80	74.94			
Left Leg Tourniquet Scen2 Groups 2 and 4	Group Two (NM, M, NM)	8	48.25	14.78	1.83	.095	.103
	Group Four (M, M, NM)	10	64.60	31.36			

Tourniquet Type	Group Type	n	Mean	SD	F Statistic	One-tailed P Value	Partial Eta Squared
Right Leg Tourniquet Scen2 Groups 2 and 4	Group Two (NM, M, NM)	8	83.37	63.89	.00	.484	.000
	Group Four (M, M, NM)	10	81.90	79.31			
Left and Right Leg Total Tourniquet Scen2 Groups 2 and 4	Group Two (NM, M, NM)	8	133.87	69.17	.20	.329	.013
	Group Four (M, M, NM)	10	150.00	79.88			

For the third analysis, the combine control groups' left and right leg total tourniquet application scores were pooled across the two immersive scenarios and compared to the two experimental groups' left and right leg total tourniquet application scores, which were also pooled across the two immersive scenarios. The experimental Groups (3 and 4) demonstrated better left and right leg total tourniquet application times, (M = 173.20, SD = 85.84) than did the control Groups (1 and 2), (M = 190.60, SD = 93.26), $F(1,80) = .79$, $p = .37$ (Table 25), although, the results are not statistically significant.

Table 25: Experimental vs. Control Group Tourniquet Application Time during Immersive Scenarios

Tourniquet Type	Group Type	n	Mean	SD	*F* Statistic	One-tailed *P* Value	Partial Eta Squared
Left Leg Tourniquet Immersive Scenario	Control No Mvt Training	42	89.60	56.18	.12	.365	.002
	Experimental Mvt Training	40	85.30	54.95			
Right Leg Tourniquet Immersive Scenario	Control No Mvt Training	42	92.52	57.40	.41	.260	.005
	Experimental Mvt Training	40	84.32	57.98			
Left and Right Leg Total Tourniquet Immersive Scenario	Control No Mvt Training	42	190.69	93.26	.79	.185	.010
	Experimental Mvt Training	40	173.02	85.84			

Hypothesis Two$_b$: Analysis and Results – Lab-based Tourniquet Application Time

H2$_b$ – In the lab-based training, the experimental groups i.e., those who were trained on a moving simulator will have a slower tourniquet application time when presented to movement.

For this hypothesis, one analysis was conducted. This analysis compared the tourniquet application times in the lab-based training for Groups 1 and 2 (i.e., the two cohorts that experienced the static Advanced MATT during lab-training) to Groups 3 and 4 (i.e., the two cohorts that experienced the moving Advanced MATT in the lab-training).

The experimental groups reported worse (slower as predicted in the hypothesis) overall left and right total tourniquet application time (M = 152.45, SD = 89.88) than did the control, (M = 143.57, SD = 85.38), *F*(1,39) = .10, *p* = .75. Worse scores were also demonstrated in the right leg tourniquet, while better scores were demonstrated for the experimental group in the left leg tourniquet as seen in Table 26. Although not statistically significant, the slower tourniquet times

reported by the experimental groups may be reflective of receiving movement for the first time; this is explained in more detail in the Discussion section.

Table 26: Experimental versus Control Group Tourniquet Application Time during Lab-Training

Tourniquet Type	Group Type	n	Mean	SD	F Statistic	One-tailed P Value	Partial Eta Squared
Left Leg Tourniquet Lab	Control No Mvt Training	21	62.86	35.41	.46	.250	.012
	Experimental Mvt Training	20	56.30	25.54			
Right Leg Tourniquet Lab	Control No Mvt Training	21	78.57	66.38	.42	.260	.011
	Experimental Mvt Training	20	93.40	79.15			
Left and Right Total Tourniquet Lab	Control No Mvt Training	21	143.57	85.38	.10	.375	.003
	Experimental Mvt Training	20	152.45	89.88			

Overall Participant Survey Results

The participant reaction survey (Appendix F) was given following the first immersive scenario. Participants were asked to comment on the scenario they just experience only (immersive scenario one), not on the previous lab-training. This survey was used to assess reactions as described in hypotheses three, four, and five.

Table 27 lists the subscales, number of questions per subscale, average scores, maximum score, and Likert label. Each of the subscales were highly rated by the participants.

Table 27: Subscales Average Scores and Overall Ratings

Subscales	Number of Questions Per Subscale	Average Scores Observed	Maximum Score	Likert Label
Utility	5	27	35	Somewhat Agree
Perceived Realism	4	19	28	Somewhat Agree
Presence	6	32	42	Somewhat Agree
Affective Reactions	5	26	35	Somewhat Agree
Perceived Difficulty	4	20	28	Somewhat Agree
Self-Efficacy	5	26	35	Somewhat Agree
Overall	1	6	7	Agree

The subscale descriptive statistics for each of the four groups are separated in Table 28. This survey was given to the participants following the immersive scenario one. The mean scores between each of the subscales are very similar within each of the four groups, regardless of the movement conditions. Hypothesis three, four, and five discuss additional survey analysis and results.

Table 28: Participant Overall Survey Means

	Participant Survey Group	n	Mean	SD	F Statistic	One-tailed P Value	Partial Eta Squared
Utility	1.00	13	28.15	4.22	.908	.224	.069
	2.00	8	28.12	5.82			
	3.00	10	25.20	4.57			
	4.00	10	28.00	5.01			
Perceived Realism	1.00	13	19.00	2.16	.230	.219	.018
	2.00	8	19.50	2.68			
	3.00	10	18.50	2.88			
	4.00	10	18.90	2.60			
Presence	1.00	13	32.00	4.69	.207	.446	.017
	2.00	8	32.75	5.36			
	3.00	10	31.30	4.24			
	4.00	10	32.70	4.37			
Affective Reactions	1.00	13	25.69	3.99	.594	.312	.046
	2.00	8	27.25	4.95			
	3.00	10	25.70	3.78			
	4.00	10	27.60	4.25			
Perceived Difficulty	1.00	13	20.85	3.05	2.122	.056	.147
	2.00	8	19.94	3.14			
	3.00	10	20.40	3.13			
	4.00	10	17.80	2.74			
Self-Efficacy	1.00	13	25.27	3.93	.567	.320	.044
	2.00	8	24.75	3.33			
	3.00	10	25.35	3.11			
	4.00	10	26.70	2.98			

	Participant Survey Group	n	Mean	SD	F Statistic	One-tailed P Value	Partial Eta Squared
Overall Rating	1.00	13	6.15	.69	.523	.335	.041
	2.00	8	6.06	1.15			
	3.00	10	5.90	.74			
	4.00	10	5.50	2.17			

Figures 29 – 35 show the subscales graphically, with more explanation given in the Discussion section. Beginning with the construct utility, as seen in Figure 29, control Groups 1 (NM, NM) and 2 (NM, M) and experimental Group 4 (M, M) rate utility the highest, with experimental Group 3 (M, NM) the lowest. Figure 30 displays perceived realism with similar rating across the groups as did presence, Figure 31. Figure 32 shows the graph for affective reaction with the two groups receiving movement (Groups 2 and 4) rating affective reaction higher than the two groups' not receiving movement (Groups 1 and 3). Perceived difficulty is graphed in Figure 33 with Group 4 (M, M) rating difficulty the lowest. Self-efficacy is graphed in Figure 34 with Group 4 (M, M) rating self-efficacy the highest. The last graph, displays overall reaction training ratings, Figure 35.
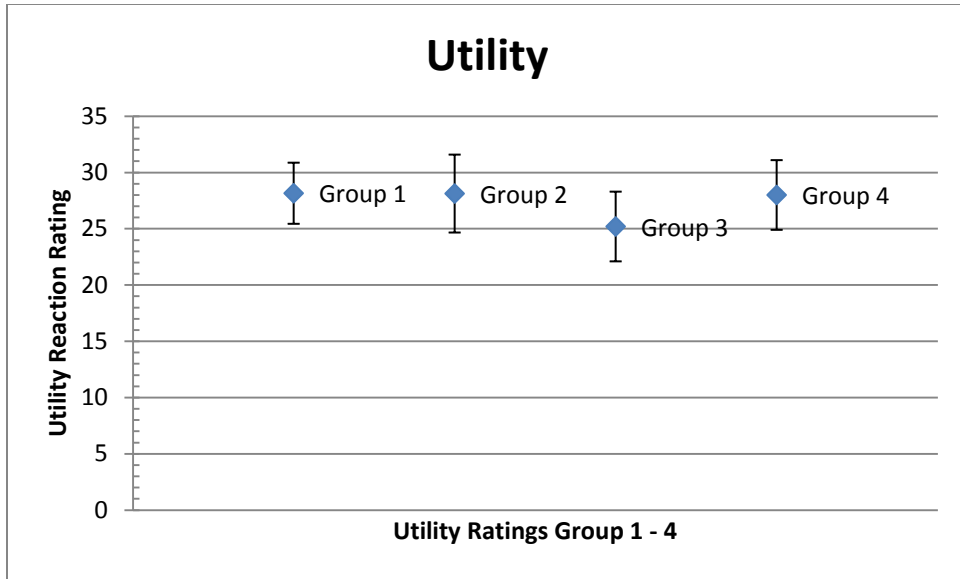
Figure 29: Overall Means for Utility
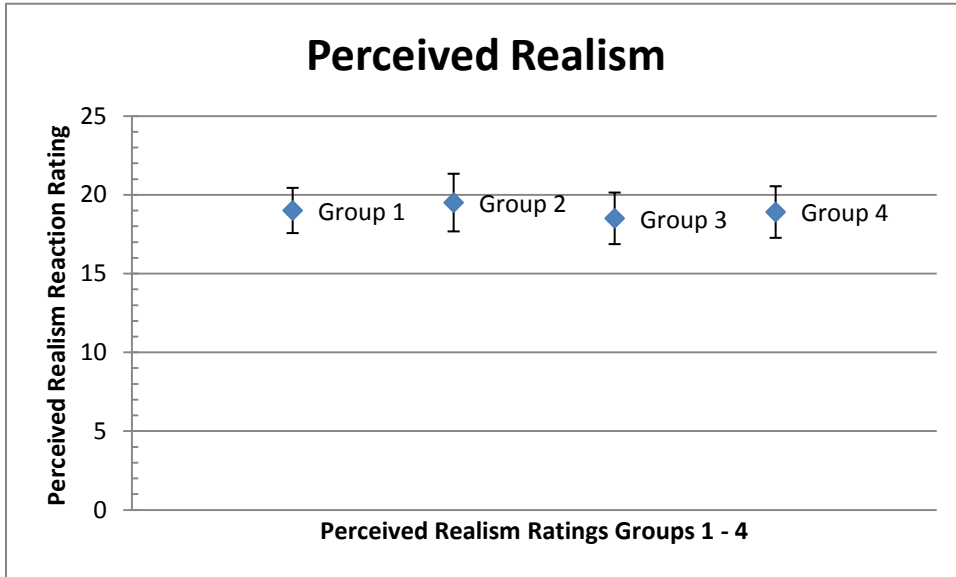
Figure 30: Overall Means for Perceived Realism
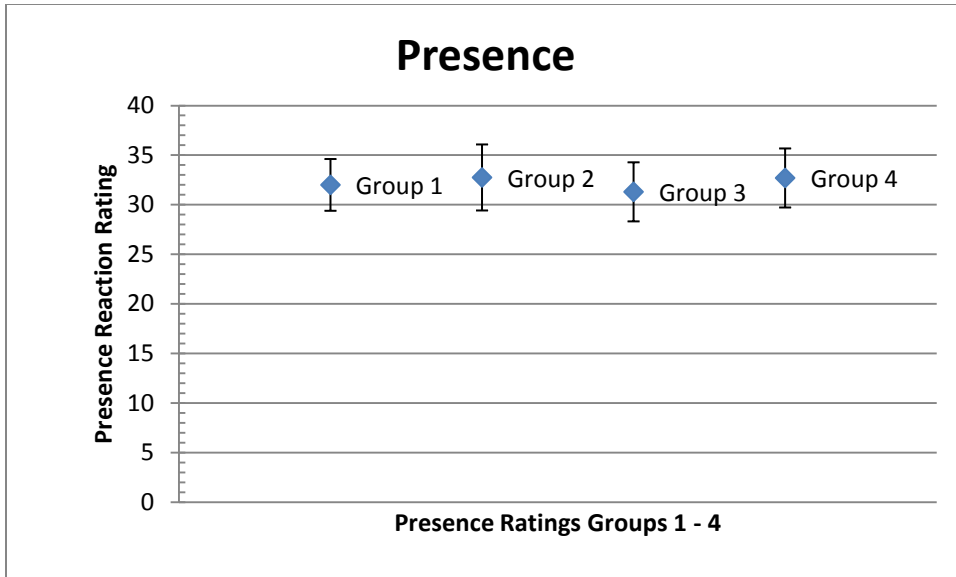
Figure 31: Overall Means for Presence
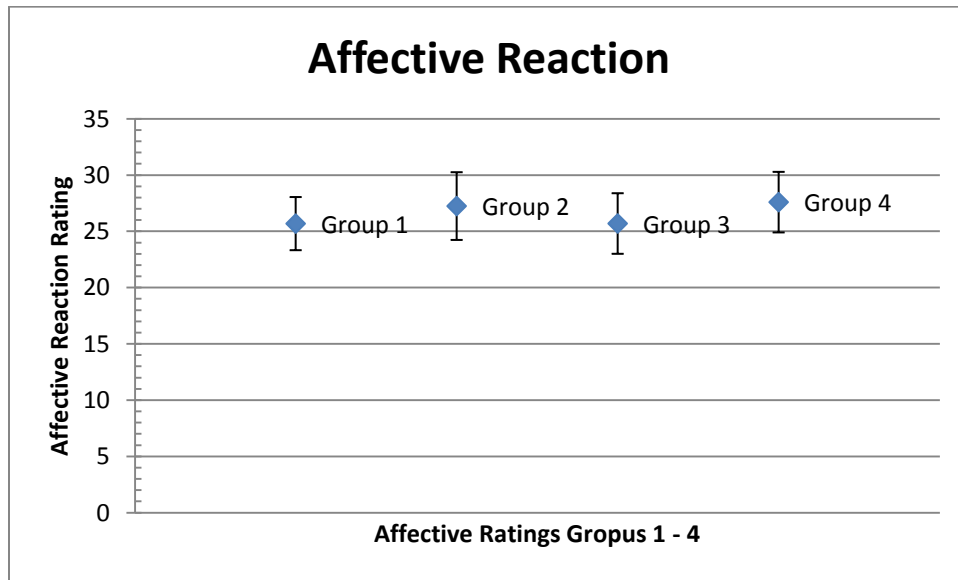
Figure 32: Overall Means for Affective
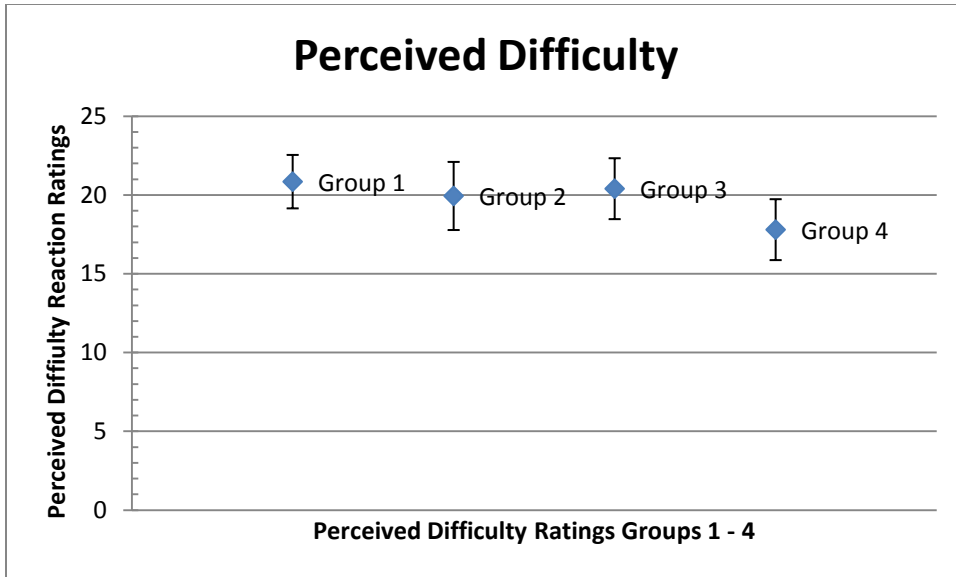
Figure 33: Overall Means for Perceived Difficulty
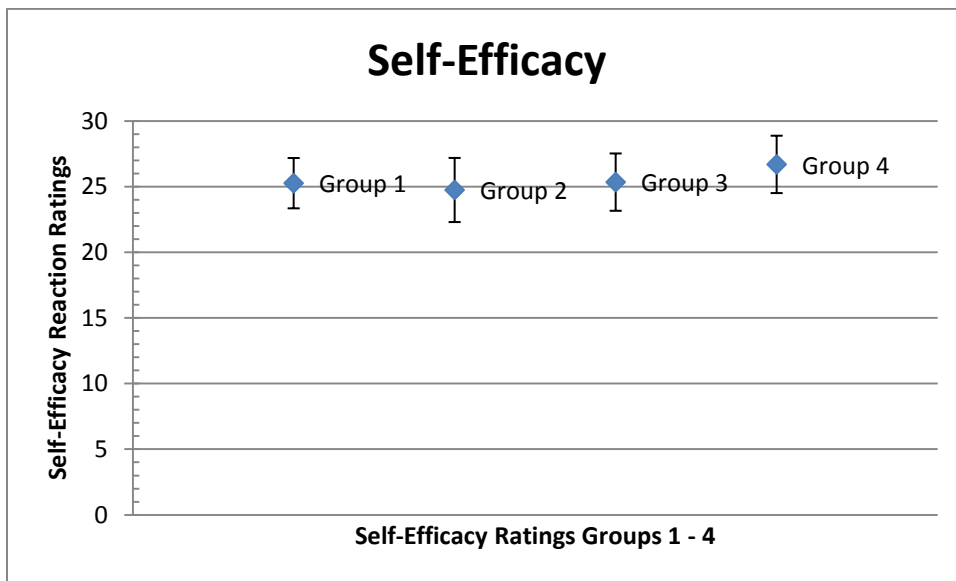
Figure 34: Overall Means for Self-Efficacy
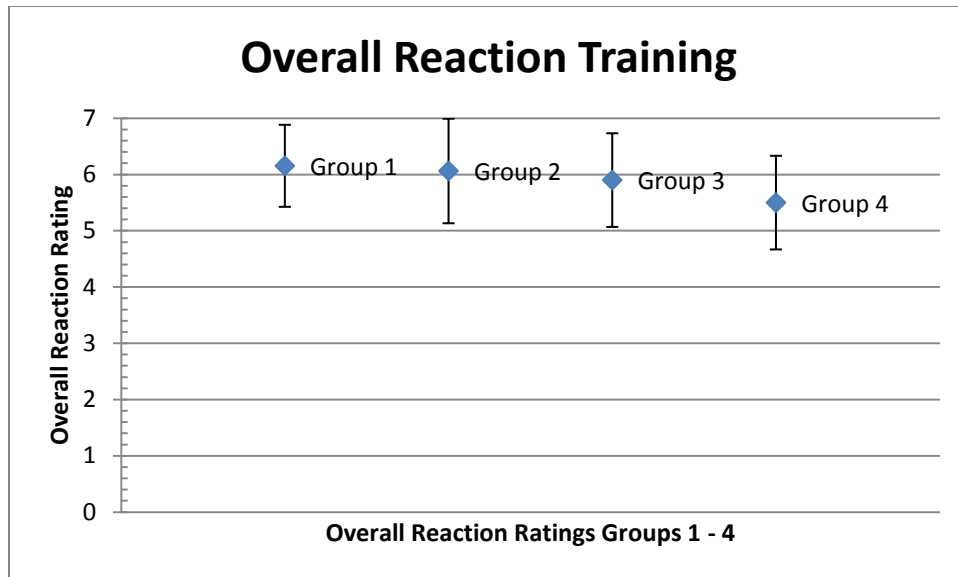
Figure 35: Overall Means for Overall Reaction Training Rating

<u>Hypothesis Three: Analysis and Results – Lab-based Perceived Realism</u>

H3 – Participants who complete a tourniquet training <u>immersive scenario</u> on the MATT simulation with animatronics (groups 3 and 4) will report <u>higher perceived realism scores</u> than participants who complete the training on a static version (groups 1 and 2) of the MATT.

For this hypothesis, one analysis was conducted. This analysis compared the perceived realism scores for Groups 1 and 3 (i.e., the cohorts receiving the static Advanced MATT during the lab-training) to Groups 2 and 4 (i.e., the cohorts receiving the moving Advanced MATT during the lab-training). The Groups 2 and 4 reported higher (better) perceived realism scores ($M = 17.22$, $SD = 3.06$) than did the Groups 1 and 3, ($M = 16.43$, $SD = 2.74$), $F(1,39) = .75$, $p = .39$, as seen in Table 29.

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Table 29: Movement versus Non-Movement during Immersive Scenario One – Perceived Realism

Reaction Type	Group Type	n	Mean	SD	F Statistic	One-tailed p Value	Partial Eta Squared
Perceived Realism	Mvt Immersive Scenario	18	17.22	3.06	.75	.195	.02
	No Mvt Immersive Scenario	23	16.43	2.74			

Hypothesis Four: Analysis and Results – Lab-based Presence

H4 – Participants who complete a tourniquet training <u>immersive scenario</u> on the MATT simulation with animatronics (groups 3 and 4) will report <u>higher presence scores</u> than participants who complete the training on a static version (groups 1 and 2) of the MATT.

For this hypothesis, one analysis was conducted. This analysis compared the presence scores for Groups 1 and 3 (i.e., the cohorts receiving the static Advanced MATT during the lab-training) to Groups 2 and 4 (i.e., the cohorts receiving the moving Advanced MATT during the lab-training). The Groups 2 and 4 reported higher (better) presence scores (M = 29.17, SD = 4.84) than did the Groups 1 and 3, (M = 28.00, SD = 4.28), $F(1,39) = .65$, $p = .42$, as seen in Table 30.

Table 30: Movement versus Non-Movement during Immersive Scenario One – Presence

Reaction Type	Group Type	n	Mean	SD	F Statistic	One-tailed p Value	Partial Eta Squared
Presence	Mvt Immersive Scenario	18	29.17	4.84	.65	.42	.02
	No Mvt Immersive Scenario	23	28.00	4.38			

Hypothesis Five$_a$: Analysis and Results – Lab-based Self-Efficacy

H5$_a$ – Participants who complete <u>lab-based</u> tourniquet training on the MATT simulation with movement will report <u>higher self-efficacy scores </u>than participants who complete the training on a static version of the MATT.

For this hypothesis, one analysis was conducted. This analysis compared the self-efficacy scores for Groups 1 and 2 (i.e., the cohorts receiving the static Advanced MATT during the lab-training) to Groups 3 and 4 (i.e., the cohorts receiving the moving Advanced MATT) during the lab-training. The experimental Groups 3 and 4 reported higher scores, (M = 22.97, SD = 3.35), than did the control Groups 1 and 2, (M = 21.93, SD = 3.94), $F(1,39) = .05$, $p = .83$, Table 31. This analysis evaluated the downstream effects of the lab-based training (i.e., with or without the animatronics in the lab-based practice) on self-efficacy.

Table 31: Experimental versus Control Group Self-Efficacy during Lab Training

Reaction Type	Group Type	n	Mean	SD	F Statistic	One-tailed p Value	Partial Eta Squared
Self-Efficacy	Control No Mvt Training	21	21.93	3.94	.83	.185	.02
	Experimental Mvt Training	20	22.97	3.35			

Hypothesis Five$_b$: Analysis and Results – Immersive Self-Efficacy

H5$_b$ – Participants who complete a tourniquet training <u>immersive scenario</u> on the MATT simulation with movement will report <u>higher self-efficacy scores</u> than participants who complete the training on a static version of the MATT.

For this hypothesis, one analysis was conducted. This analysis compared the self-efficacy scores for Groups 1 and 3 (i.e., the cohorts receiving the static Advanced MATT during immersive scenario one) to Groups 2 and 4 (i.e., the cohorts receiving the moving Advanced MATT during immersive scenario one). Groups 2 and 4 had higher self-efficacy scores (M = 22.94, SD = 3.86) than did Groups 1 and 3 (M = 22.04, SD = 3.53), $F(1,39) = .61$, $p = .44$, Table 32.

Table 32: Movement versus Non-Movement during Immersive Scenario One – Self-Efficacy

Reaction Type	Group Type	n	Mean	SD	F Statistic	One-tailed p Value	Partial Eta Squared
Self-Efficacy	Mvt Immersive Scenario	18	22.94	3.86	.61	.220	.02
	No Mvt Immersive Scenario	23	22.04	3.53			

Overall Reaction Training Rating

Overall reaction training ratings were out of a score of seven. Although not significant, the groups receiving no movement during the immersive scenario one rated the overall training slightly higher than the group receiving movement, Table 33.

Table 33: Movement Influence in Immersive Scenario – Overall Training Rating

	Scenario Receive Mvt Survey	n	Mean	SD	F Statistic	Sig.	Partial Eta Squared
Overall	Movement	20	5.70	1.59	1.11	.298	.028
	No Movement	21	6.12	.86			

<center>Participant Comments</center>

Participants were asked to provide comments about the most valuable and least valuable portions of training. Table 34 captures some of the unique "most valuable" comments, while Table 35 captures the "least valuable" comments. In general, the feedback captured useful overall impressions from the participants, which may be important to future experimental tests. Overall, they suggest that Advanced MATT was helpful in training. To view all the comments see Appendices H and I.

The "most valuable" comments addressed issues such as confidence and realism, as well as the immersive features within the scenario (e.g. battlefield effects). "Least valuable" comments addressed the desire for a scenario that would stress them more, and they requested additional special effect including smells, sounds, and battle gear on the Advanced MATT. Participants also requested that more injuries be provided, that there be less waiting time, and that they be given initial instruction. It is interesting to note that more negative comments were given by those who did not receive movement, especially those in Group 1 (NM, NM, survey). Reviewing this qualitative data, movement appears to have had an impact.

Table 34: Participant Comments on the Most Valuable Aspects of Training

Received Movement during Scenario One	Received No Movement during Scenario One
• The best angle to apply the strap, it should be directly on the "high" artery • Hands on training with a moving mannequin helped prepare with real life scenario's (sic) • Developing confidence in my skills with bleeding control • How tight the tourniquet was applied • Hands on application of the CAT® on the MATT => very realistic • More realistic that what I have trained before • Realism • MATT itself • The movement of the simulated amputee made training more realistic • The movement of the MATT provided a real-life experience • Hands-on practice applying a tourniquet w/ immediate definitive feedback on how to tighten the tourniquet other than verbalization	• Now, I'm thinking about this situation as if it were real • Actually putting the tourniquet on an amputated leg • The different situations I was put in… • New learning experience • Seeing the bleeding stop • Training broken down into steps • The realistic sounds and feeling of application of tourniquet • Having to actually stop the "bleeding" • Having a mannequin that stopped squirting blood when you had the tourniquet on right • Feedback after each scenario • Simulated bleeding • Nighttime training and stress control • Applying the tourniquet through simulated battle situation which was very realistic • Scenario with realistic sounds and light environment good training • Opportunity to learn how to stop bleeding

Table 35: Participant Comments on the Least Valuable Aspects of Training

Received Movement during Scenario One	Received No Movement during Scenario One
• Wish there was a review before using MATT • A bit too easy since variables like body armor and other Soldiers were absent • I would prefer a full scenario possibly with a group • The training hands on with the MATT should be prior to the scenario • Focusing on just tourniquet? Procedures on other types of injuries would be great at this standard or level • Waiting • Limited to just the application of the tourniquet	• Not a whole lot of instruction • Only the lower limbs were used • Application of tourniquet without any verbal cues at beginning of each demo • Not realistic enough. If the training was a combat simulation, it should have been done in combat gear, i.e. body armor, Kevlar, assault pack and gloves. Screaming or moaning from the MATT would make it more realistic. • Only legs were used • No variation in where to place the tourniquet on which limb • Is not as realistic as performing on a live buddy (Note: Group 1, NM, NM, survey) • The lack of smell and silence from the casualty • More time should have been spent showing right and wrong ways to apply the tourniquet • The surrounds seemed too fake to make me hurry • Full treatment to MATT would make the training more realistic. It is hard for medical personnel to focus on only one part of patient care and just leave the rest undone. A team exercise may improve the experience and would also be more realistic.

Discussion

Controlling bleeding using a tourniquet is an important skill for military first responders. Standard, static medical simulation tourniquet trainers help provide training opportunities to increase skill level; however, more effective tourniquet simulators may be available. The Advanced MATT lower limb simulator is a dynamic tourniquet trainer incorporating limb movement, and this study empirically investigated whether the Advanced MATT's animatronics meaningfully affected tourniquet sustainment training.

During this experiment, participants completed three trials with the Advanced MATT. Lab-based training (trial zero) involved a static training experience using the Advanced MATT (with movement deactivated) for the control groups, while the experimental groups experienced the Advanced MATT with the animatronic movement. In the lab-training the room lights remained on. During the two immersive scenarios (trials one and two), battlefield effects were incorporated (i.e., strobe lighting, battlefield sounds, and fog) and the room's lights were darkened. Each of the four groups had the opportunity to experience the Advanced MATT with animatronics and without animatronics during the two immersive scenarios.

The participants were timed on reaction (i.e., time to reach the casualty) and tourniquet application (i.e., time to apply a tourniquet to the left and right legs), and their reactions to the training experience were documented. This discussion focuses on the overall training effect, reaction time, participant reactions, and the impact of movement. Implications will also be discussed relating to future training involving human patient simulator movement.

Key Findings

First, an analysis was conducted to evaluate the overall utility of the Advanced MATT simulator to support tourniquet training. There were significant positive training effects found between the three training trials (lab, scenario one, and scenario two), specifically for reaction time, left leg tourniquet time, left and right leg total tourniquet time, and total exercise time. These results imply that the Advanced MATT simulator was effective as a training aid.

It is important to note that tourniquet training is a critical skill that all Soldiers learn in basic training. Furthermore, many of the participants in this study were highly experienced. Yet, despite their prior training and operational experience, trainees' performance improved across each trial. In other words, the Army Reserve participants are all technically proficient in the CAT® tourniquet and yet have benefited from this simulation-based training exercise.

The second key analysis examined reaction times during the lab-based training, immersive scenario one, and immersive scenario two. As mentioned earlier, reaction time describes the time from crossing the door threshold to first laying hands on the Advanced MATT, while tourniquet application time is the time to successfully apply a tourniquet. A statistically significant difference in average reaction times was discovered between the experimental groups (3 and 4, who were lab-trained with movement) and the control groups (1 and 2, who received the static version of the Advanced MATT during lab-training). The experimental group displayed the better (faster) reaction times. The experimental groups also had better left leg tourniquet application times and left and right leg total tourniquet application times. In other words, the experimental groups who practiced on Advanced MATT with its animatronics activated later outperformed the control participants who practiced on the static

version of the mannequin. These results imply that the experimental groups' experience with the moving Advanced MATT in the lab-based training translated to enhanced reaction time in an immersive trial. Although the reaction time differences between the control and experimental groups were modest, even small improvements to reaction time may translate into meaningful effects on the battlefield.

Specifically, the effect size across the three trials was *small* according to Cohen's classification (1992). This may imply the possibility of type I errors. Additional participants will help to address this issue in future testing and will be discussed further in the Conclusions section.

The third analysis explored participants' reactions to training. A survey asked participants for their thoughts on utility, perceived realism, presence, perceived difficulty, affective reactions, and self-efficacy. Although the results of the surveys were not statistically different across groups, interesting trends were uncovered. The same pattern of responses, from across the four groups, was found for each of the subscales. Group 1 (NM, M, survey) rated each subscale moderately high across the six categories (utility, perceived realism, perceived difficulty, presence, affective reactions, and self-efficacy). Group 2 (NM, M, survey) rated the constructs higher than did Group 1, and in most cases rated each subscale the highest of all four groups. In contrast, Group 3 (M, NM, survey) offered the lowest ratings. Group 4 (M, M, survey) also provided high ratings for each subscale, with the exception of "perceived difficulty."

First, consider the trends on the utility subscale. Groups 1, 2, and 4 all rated utility highly (≈ 28.09, "agree"); however, Group 3 rated utility the lowest (25.20, "somewhat agree"). Group 3's noticeably lower rating may be a result of these participants first being exposed to

animatronics in the lab-based setting and then having those features removed during the immersive scenario (i.e., the trial that the reaction survey addressed). That is to say, Group 3 participants' may have perceived the immersive scenario as less useful because they could compare this experience to their prior lab-based training that involved the moving Advanced MATT.

The second discussion point was exposed on the perceived difficulty subscale. Groups 1, 2, and 3 all rated perceived difficulty higher ($\approx$ 20.40, "somewhat agree") than Group 4 (17.80, "neutral"). Group 4's lower rating may be a result of these participants being exposed to animatronics in the lab-based training and again in immersive scenario one. Specifically, two trials involving animatronics may have had an impact on lowering Group 4's perceived difficulty rating.

The third discussion point was revealed on the self-efficacy subscale. Groups 1, 2, and 3 all rated self-efficacy lower ($\approx$ 25.12, "somewhat agree") than Group 4 (17.80, "neutral"). Group 4's higher rating may again, be a result of receiving animatronics in the lab-based training as well as in immersive scenario one. Furthermore, an increase in self-efficacy may have an impact on increasing performance (as seen in Bandura, 2010; Nishisaki, et al., 2007).

Finally, it is interesting to note that; overall, movement did not appear to have a negative impact. It did not considerably slow reaction or tourniquet application times, even on its first introduction to participants. At best there may be small improvement as seen the significant overall training results. It may improve subjective ratings such as utility, perceived realism, perceive difficulty, presence, and self-efficacy, as shown in the trends.

The ROI of increased performance and potential self-efficacy, specifically, may provide a downstream benefit. Since there is not an additional cost-impact (either financially or to the effectiveness or efficiency of training), movement-based simulation may provide more benefits such as improved operational times (faster reaction and left leg tourniquet application) as seen with the experimental groups (3 and 4) trained with movement.

CHAPTER SIX: CONCLUSIONS, LIMITATIONS, LESSONS LEARNED AND FUTURE RESEARCH

<u>Relevance of Movement Research</u>

Tourniquet use is a critical military live-saving procedure that all Soldiers first learn during basic training. Traditionally, Soldiers practice applying tourniquets to each other (buddy training), use simple part-task simulators, or even practice on blocks of wood. These training aids, however, all lack a key feature of real-world tourniquet application: movement. Those injured may move in pain, grab at their caregivers, or fight care. Adding movement to medical simulators may increase their efficacy and engender improved performance on the battlefield. This study examined the effect of a moving part-task human-patient simulator on Soldiers' tourniquet application performance.

<u>Summary of Research Findings and Conclusions</u>

Research findings include the training effects across the three trials, participant reactions to the training, and left and right leg differences. Repeated measures analysis illustrates overall significant training effects across the three trials, with trial three (immersive scenario two) yielding the best scores for all four groups (controls and experimental). These results suggest that the Advanced MATT can be a viable training aid.

When analysis was limited to the movement component, it appears the groups receiving movement (i.e., 3 and 4) slightly outperformed the non-movement groups (i.e., 1 and 2), the majority of the time—however, these results generally failed to reach statistical significance. It is

possible that movement may create a greater sense of urgency than a static simulator, therefore affecting performance.

Participant reactions were not statically different across the four groups. However, these data trended toward significance, especially with the utility subscale. Overall, the groups experiencing movement rated the constructs higher. An exception was Group 4 (i.e. who were lab-trained with movement and received movement during immersive scenario one) who rated perceived difficulty lower and self-efficacy higher than Groups 1, 2, or 3. It is thought that the influence of movement affected both the perception of difficulty and self-efficacy over the two trials. The outcomes are a trend that communicates the importance movement plays in training.

Left Versus Right Leg

Differences were found in the tourniquet application times between the left (above knee amputation) and right (below knee amputation with bones exposed) legs, as seen in Figure 36. Although, not-hypothesized, this finding discovered that participants reacted differently to the Advanced MATT's left and right legs. One possibility is that the severity of the right leg (bones exposed) would either lead to faster (looks worse) or slower (this is going to take longer, or is intimidating) tourniquet application. Another explanation, as noted by informal participant comments during the lab-training (trial zero), was that participants were visually overwhelmed and more intimidated by the right leg, therefore, applying a tourniquet to the left leg at a different rate than the right leg. Similarly, during the experiment some participants would say things such

as 'I keep having a hard time with this leg.' This type of comment would be heard throughout the three trials.

Results showed that the right leg times were slower in the lab training as the shrapnel and slivered bones on that leg may have had an effect on the tourniquet application. It was observed that some individuals had to adjust tourniquet location once they realized that shrapnel was in the leg, potentially slowing down tourniquet time. Although in both immersive scenarios, the mean times for the left and right leg tourniquet were similar. Furthermore, it is important to note that the right leg did have slightly more movement characteristics than the left leg which may have affected participants' time to apply the tourniquet. There is not enough information to draw solid statistical conclusions, yet it does warrant future testing.

Figure 36: MATT Leg Injury Differences

The differences in the left and right leg are relevant for military medicine. On the battlefield there are many different types of amputations, two of which were seen in Figure 36. If the results reported in this study are indeed a trend in tourniquet application, it is important to examine those differences further. For example, additional testing may narrow down the differences between the leg and right leg. Furthermore, those lessons learned may translate into the schoolhouse where more practice may occur applying a tourniquet to many different types of amputations.

Limitations and Suggestions for Experimentation

Limitations exist from the scope of experimentation. The use of water as simulated blood, the use of a prototype, and operational requirements of the instructors were factors in the experiment. Additionally, experimental limitations—notably the number of participants— affected this study. These limitations are discussed, along with suggestions for future experimentation.

First, the sites requested that water was used, not the traditional simulated blood. Instructors requested this modification to prevent participants' uniforms from becoming stained. Future research into the question of simulated blood will need to address the appropriate body temperature, viscosity, and smell of human blood. How much meaningful variation exists, between water and simulated blood, in a training setting remains an open question.

Second, only one Advanced MATT unit was available. Since the experiment used one unit, time was spent refilling the unit with water (i.e., blood container). This reset time created a

wait for the participants. In future testing, it would be more efficient to have two units available to make experimental reset faster, thus reducing participant downtime. Furthermore, the one unit had the same injuries (i.e., left leg amputation above the knee and right leg amputation below the knee) throughout the three trials. The addition of different injuries may be helpful for future training.

Participants

A power analysis was conducted prior to testing. It was determined that 128 participants were needed for the experimentation, assuming medium effect size. A total of 41 participants were recruited. This low number was due to logistical limitations (i.e., availability of Reserve Soldiers) and reduced the statistical power of the analysis, which may explain why some of the results have interesting trends, yet failed to reach statistical significance. Future testing, with a larger number of participants, inclusive of the lessons learned may help to create statistical significance with reaction, tourniquet application, and participant reaction surveys.

Lessons Learned

Since this is the first test studying the effects of simulator-based movement on lower limb tourniquet training, lessons were learned. Some lessons reflect the visual differences between the left and right leg amputations, others the lack of injury variation, and finally others the

opportunity to practice tourniquet application. These lessons learned may help develop future experimental designs.

Although many of the participants were experienced in tourniquet application, some commented that it would be useful to have more training before the Advanced MATT testing. This additional training would allow tourniquet application remediation, especially if that skill had not been practiced for a while. Providing more time to physically practice tourniquet application may be helpful for future testing.

The injuries of the left and right leg amputations did not change between the three trials (i.e., no variation in injuries). Yet, since there are visual differences between the left and right leg amputations, there may be additional research in examining the individual legs in more detail. Studying groups of participants over smaller testing increments, reviewing the results, followed by a secondary test that implements lessons learned may prove beneficial to furthering the study of movement on tourniquet application. Additional research into the differences in the left and right leg amputations may help with the future of medical simulation training aids to ensure the Warfighter has the appropriate training to successfully accomplish mission requirements.

Research Recommendations

Lessons learned from research are valuable to advance future experimentation. Since tourniquet application training is beginning to involve limb movement, future research will play a role in further defining this technology. Recommendations for future research investigating movement in tourniquet application includes: increasing training opportunities, longitudinal

testing, identification of the left and right leg differences (as seen in the Advanced MATT), limb injury variation, and increasing scenario complexity.

Participant recommendations include more intensive tourniquet application training, which would incorporate a larger "crawl" (i.e., more practice) portion before testing. The additional training would help participants' feel more comfortable and become faster and more efficient when applying a tourniquet, prior to testing. Additionally, it is hypothesized that this additional training would have an impact on decreasing the standard deviation of the reaction and tourniquet application times. Furthermore, since medical skills are perishable, it would be interesting to see the training effects on tourniquet application times. The testing scenario would train tourniquet application on a part-task simulator and allow practice time. The participant would then test tourniquet application time on the Advanced MATT with animatronics, followed by a final post-test on the original training simulator (or vice versa). Not only would this allow the participant addition training time, in essence it would also test transfer of skill and reduce testing downtime.

Using data from previous experimentation, longitudinal testing of a sample may be useful to study the effects movement-based simulation has on skill retention. Going back to the same reserve sites after six months or a year and re-testing the participants on the Advanced MATT with movement employed during an immersive scenario would compare the changes in performance times. This would essentially evaluate the effect movement has on longitudinal testing.

In order to address the visual differences between the left and right leg, future experimentation may include evaluation of teams of two. First the team would enter a scenario;

the first participant would put a tourniquet on the left leg, while the second participant would put a tourniquet on the right leg. During the second scenario, the participants would apply a tourniquet on the opposite leg. A survey would capture subjective perceived differences experienced for each leg following the trials. By allowing each participant to apply a tourniquet to each leg, it is desired to discover if amputation differences between the two legs, along with the movement component, play a role in the time it takes to apply a tourniquet. These lessons learned could be translated to teaching modules at the schoolhouse.

The addition of more complex scenarios or multiple injuries, once tourniquet skills were mastered, could address the effects of movement when amputation, breathing, or upper body injuries were present. Providing complex scenarios that include multiple injuries and decisions regarding treatment may have an effect on tourniquet application times. This may be accomplished by incorporating Advanced MATT units with upper body movement, once developed, to assist with the creation of additional scenarios inclusive of upper and lower body movement and injuries. Additionally, adding a live actor for the upper portion may increase realism. Furthermore, the addition of complex scenarios may also require teams of participants to treat the casualty providing training in communication and teamwork skills. This additional complexity could create more differences in overall performance from trial to trial.

Additional study recommendations are endless. Simulation-based movement in tourniquet training is in the infancy stage. Since this study provides a first look at the reaction and performances times, as well as the subjective evaluation of movement, the future recommendations listed above are all viable ways to continue research. As the upper body limbs and advancements in simulator breathing and speaking improve, they too continue to expand the

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limitless opportunities to test movement in simulation training, not only in military training, but in civilian healthcare as well.

APPENDIX A: IRB APPROVAL LETTER

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

Approval of Human Research

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

To: **Christine Allen** and Co-PI: **Sae L. Schatz**

Date: **July 13, 2011**

Dear Researcher:

On 7/13/2011, the IRB approved the following minor modification to human participant research until 07/11/2012 inclusive:

Type of Review:	IRB Addendum and Modification Request Form Expedited Review Category #7 This approval includes a Waiver of Written Documentation of Consent
Modification Type:	Addition of Teresita Sotomayor and William (Bill) Pike as researchers; revised Informed Consent with additional researcher names approved for use.
Project Title:	Bleeding Control Using Multiple Amputee Trauma Trainer in Medical Simulation: Comparison of Movement Versus Non-Movement in Training
Investigator:	Christine Allen
IRB Number:	SBE-11-07752
Funding Agency:	RDECOM-STC
Grant Title:	
Research ID:	N/A

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

If continuing review approval is not granted before the expiration date of 07/11/2012, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

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

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

On behalf of Kendra Dimond Campbell, MA, JD, UCF IRB Interim Chair, this letter is signed by:

Signature applied by Joanne Muratori on 07/13/2011 02:59:03 PM EDT

IRB G coordinator

APPENDIX B: CONSENT FORM

University of Central Florida

Bleeding Control Using Multiple Amputee Trauma Trainer in Medical Simulation: Comparison of Movement Versus Non-Movement in Training

Informed Consent (A2)

Principal Investigator(s):	Christine Allen Sae Schatz, Ph.D.
Sub-Investigator(s):	Matthew Hackett, Bill Pike, and Teresita Sotomayor
Sponsor:	Army Research Laboratory, Simulation Technology and Training Center
Investigational Site(s):	Army Reserve Centers: 1) ARMEDCOM Tampa, Florida and 2) 143rd Orlando, Florida

Introduction: Thank you for participating in this study. It is aiding the Army in addressing the effects of medical simulation bleeding control training modalities. After reading the consent form, you will be asked to supply some background information. Afterwards you will be given a 30 minute pre-training lecture and randomly divided into four groups. Then, you will individually go through a lab-based training followed by a survey of your experiences and then two immersive training scenarios followed by surveys capturing your experience. Although your portions will only be a little over an hour, this training and testing experience will take the majority of the day as your colleagues receive their opportunity to work through the training. You will have an area to wait before and after your training cycle. We will finish by debriefing the study and answering any questions.

First responders are taught to use the Combat Application Tourniquet® (CAT®) to stop bleeding from limbs subjected to severe injury such as amputation, gunshot, or severe lacerations. A training aid such as the Multiple Amputee Trauma Trainer (MATT) provides tourniquet training using a lifelike bilateral lower limb amputee. MATT is currently used in the schoolhouse curriculum for first responder training. You are invited to take part in this research as an Army reserve unit.

The purpose of this research is to study the effects of simulator movement for tourniquet application using observation and participant surveys.

You must be 18 years of age or older to participate.

The U.S. Army Research Laboratory Simulation and Training Technology Center is conducting the research. The person doing this research is Christine Allen, Research Analyst for the Army and dissertation candidate with the University of Central Florida.

What you should know about a research study:
- Someone will explain this research study to you.
- A research study is something you volunteer for.
- Whether or not you take part is up to you.
- You should take part in this study only because you want to.
- You can choose not to take part in the research study.
- You can agree to take part now and later change your mind.
- Whatever you decide it will not be held against you.
- Feel free to ask all the questions you want before you decide.

Purpose of the research study: In military training, it is often necessary to test existing training equipment to understand innovations in simulation effect with first responder training. The testing helps to verify and validate technology, while showing potential usefulness. This information can be used show the importance of having specific equipment and modalities at all training sites. The research being conducted today investigates bleeding control intervention. What the researchers' want to learn is: 1) the Multiple Amputee Trauma Trainer (MATT) effective and efficient and 2) how do first responders perceive the MATT simulator?

What you will be asked to do in the study: If you decide to participate the following is a list of procedures that you will be asked to perform. The procedures' approximated times are noted. You do not have to answer every question or complete every task.

If you do decide to participate the research study follows these steps:
- Introduction and directions ....[3 minutes]
- IRB consent form ....[5 minutes]
- Demographic information ....[5 minutes]
- Pre-training lecture ....[30 minutes]
- Random group assignment ....[5 minutes]
- Lab-based training ....[3 minutes]
- Reactions survey ....[5 minutes]
- Immersive scenario$_1$ ....[3 minutes]
- Reactions survey ....[5 minutes]
- Immersive scenario$_2$..[3 minutes]
- Reactions survey ....[5 minutes]
- Post-brief..[5 minutes]

Location: The study will take place at the Army Reserve Centers:
1) ARMEDCOM Tampa, Florida and 2) 143rd Orlando, Florida

Time required: We expect that you will be in this research study, inside of normal duty, for one to two days for a total study time under 1 hour and 30 minutes in length.

Funding for this study: This research study is part of the normal job duties of the Army Research Laboratory, Simulation Technology and Training Center. No funding is provided to UCF.

Risks: There are no reasonably foreseeable risks or discomforts involved in taking part in this study.

Benefits: We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include learning more about simulation technology's, the research process, and experimental procedures.

Compensation or payment: There is no direct compensation for taking part in this study.

Confidentiality: The information collected on you will be anonymous and identified with a four digit number; your name will not be identified as part of this data. If photographs are taken your name and face will not be identifiable. Organizations that may inspect and copy your information include the UCF IRB, Army Research Laboratory and other representatives of UCF.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, or think the research has hurt you, talk to Christine Allen, PhD candidate, Army Research Laboratory (407) 384-5119 or by email: christine.allen2@us.army.mil.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901. You may also talk to them for any of the following:
- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You want to get information or provide input about this research.

Withdrawing from the study: The person in charge of the research study may remove you from the research study without your approval. Possible reasons for removal include failure to follow instructions of the research staff or if the person in charge decides that the research study is no longer in your best interest. The sponsor can also end the research study early. We will tell you about any new information that may affect your health, welfare or choice to stay in the research.

APPENDIX C: DEMOGRAPHIC SURVEY

DEMOGRAPHIC SURVEY (A3)

Number: _____

Group: (please circle):   a. Alpha   b. Bravo   c. Charlie   d. Delta

1. **Date:** _____

2. **Age: _____**

3. **Gender** (please circle):   a. Male   b. Female

4. **Level of Education** (please circle):   a. High School   b. Associates   c. Bachelors

         c. Other (please list): _____

5. **Current service agency** (please circle):   a. Army Reserve   b. Army National Guard

         c. Army full-time   d. other (please list): _____

6. **Years in military (served to date):   _____**

7. **Rank: _____**

8. **Current Military Occupational Specialty (MOS): _____**

         Medical (please circle):   a. CLS   b. Medic   c. other (please list): _____

9. **Have you been deployed into combat, such as Iraq or Afghanistan?** (please circle):   a. Yes
b. No

         a. **If yes, have you applied a tourniquet in <u>combat</u>?** (please circle):   a. Yes   b. No

         b. **If yes, did you feel prepared to apply the tourniquet?** (please circle):   a. Yes   b.
             No

10. **Is your current civilian job in the medical field?** (please circle):   a. Yes   b. No

         a. **If yes,** (please circle):   a. EMT   b. Paramedic   c. Other (please list): _____

         b. **Number of** years _____, months _____ in the above position (served to
             date)

11. **Have you used the Multiple Amputation Trauma Trainer (MATT) before?**

         (please circle):   a. Yes   b. No

APPENDIX D: PRE-TRAINING LECTURE

Pre-Training Lecture (Taken from doctrine CLS powerpoint)

- Bleeding is the leading preventable cause of death on the battlefield from extremity wounds.
- Combat Application Tourniquet$^®$ (CAT$^®$) is the initial method to control extremity injury.
- During Care Under Fire (CUF), the primary objective is to stop life-threatening bleeding by applying a tourniquet.
- During CUF, apply the tourniquet high on the injured limb

Tourniquet Steps (research assistants provided visual demonstration)

- Apply as high as possible
- Route self-adhering band strap through both sides of the friction adapter buckle
- Pull free running end of the self-adhering band tight with both hands and securely fasten it back on itself
- Do not adhere the band past the windlass clip
- Twist windlass rod until arterial bleeding has stopped
- Lock the rod in place with the windlass clip
- Secure windlass rod with windlass strap

APPENDIX E: SCENARIO

Scenario

Your unit is on convoy. The vehicle in front of you just rolled over from an IED. Fire is suppressed. Your job as part of CUF is to treat the lower limb bleeding of your injured medic. Once you enter the door your scenario begins.

APPENDIX F: PARTICIPANT REACTION SURVEY

Participant reactions (A9)

Number: _____

Group: (please circle): a. Alpha b. Bravo c. Charlie d. Delta

Directions: Please provide <u>honest</u> feedback about the instruction or exercise you just completed.

1. **Date:** _____

Please mark <u>one</u> box per item, indicating whether you agree or disagree with the statement:	Strongly Disagree ☹	Disagree	Somewhat Disagree	Neutral 😐	Somewhat Agree	Agree	Strongly Agree ☺
2. The MATT bleeding simulator is <u>relevant to my job</u>.	❏	❏	❏	❏	❏	❏	❏
3. I <u>disliked</u> the MATT bleeding training module.	❏	❏	❏	❏	❏	❏	❏
4. Applying a <u>tourniquet</u> to MATT is <u>similar</u> to the training I have received.	❏	❏	❏	❏	❏	❏	❏
5. I <u>plan to use</u> what I learned from the MATT training module in <u>my job</u>.	❏	❏	❏	❏	❏	❏	❏
6. I was <u>poorly prepared</u> for this training module.	❏	❏	❏	❏	❏	❏	❏
7. <u>Other personnel</u> in my agency <u>could benefit</u> from this training.	❏	❏	❏	❏	❏	❏	❏
8. I prefer a <u>mannequin</u> over the MATT to train bleeding control.	❏	❏	❏	❏	❏	❏	❏
9. Interactions with MATT <u>did not</u> seem <u>realistic</u>.	❏	❏	❏	❏	❏	❏	❏
10. Today's MATT training simulator <u>kept my attention</u>.	❏	❏	❏	❏	❏	❏	❏
11. I became a <u>little bored</u> during today's MATT training module.	❏	❏	❏	❏	❏	❏	❏
12. I feel that <u>controlling bleeding</u> on the MATT is <u>too complex</u>.	❏	❏	❏	❏	❏	❏	❏
13. After completing bleeding control on the MATT, I feel <u>less confident</u>.	❏	❏	❏	❏	❏	❏	❏
14. I was <u>focused</u> on controlling the MATT's <u>bleeding</u>.	❏	❏	❏	❏	❏	❏	❏
15. I felt like I <u>lost track of time</u>.	❏	❏	❏	❏	❏	❏	❏
16. I prefer using my <u>buddy</u> over MATT to train bleeding control.	❏	❏	❏	❏	❏	❏	❏

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
17. I <u>liked</u> the MATT bleeding training module.	❏	❏	❏	❏	❏	❏	❏
18. During training, I felt <u>emotionally</u> connected to MATT.	❏	❏	❏	❏	❏	❏	❏
19. It was <u>awkward</u> and <u>unrealistic</u> to apply a tourniquet to MATT.	❏	❏	❏	❏	❏	❏	❏
20. During the training with MATT, I <u>did not</u> feel <u>mentally alert.</u>	❏	❏	❏	❏	❏	❏	❏

Please mark <u>one</u> box per item, indicating whether you agree or disagree with the statement:	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
	☹			😐			☺
21. I thought it was <u>too difficult </u>to apply a tourniquet to the MATT.	❏	❏	❏	❏	❏	❏	❏
22. I <u>prefer</u> simulators that <u>involve movement</u>, like the MATT.	❏	❏	❏	❏	❏	❏	❏
23. The MATT has helped me feel <u>more confident</u> to handle an <u>amputation</u>.	❏	❏	❏	❏	❏	❏	❏
24. The MATT bleeding control experience felt <u>realistic.</u>	❏	❏	❏	❏	❏	❏	❏
25. <u>Controlling bleeding</u> on the MATT is <u>not very complex</u> in nature.	❏	❏	❏	❏	❏	❏	❏
26. After completing bleeding control on the MATT, I feel <u>more confident</u>.	❏	❏	❏	❏	❏	❏	❏
27. I was <u>aware</u> of my <u>surroundings</u>.	❏	❏	❏	❏	❏	❏	❏
28. I find it <u>easy</u> to apply a tourniquet to MATT.	❏	❏	❏	❏	❏	❏	❏
29. I <u>do not</u> think <u>movement is useful</u> in bleeding control training.	❏	❏	❏	❏	❏	❏	❏
30. Using the MATT, I learned <u>more efficient ways</u> to improve bleeding control.	❏	❏	❏	❏	❏	❏	❏

31. Overall, I would <u>rate today's MATT training as</u>:						
Extremely Poor	**Poor**	**Slightly Poor**	**Neutral**	**Slightly Good**	**Good**	**Extremely Good**
❏	❏	❏	❏	❏	❏	❏

32. **What was the <u>most valuable</u> part of today's training with MATT?** _____

_____

33. **What was the <u>least valuable</u> part of today's training with MATT?** _____

APPENDIX G: DATA COLLECTION FORM

MATT Data Collection Form							
Alpha, Bravo, Charlie, Delta	**ID Num ber**	**Lab, Scen1, Scen2**	**Cross Door Threshold touch MATT**	**Left tour time**	**Right time**	**Tourn Break**	**Multipl e Tourn**
EXAMPLE - Alpha	1123	lab	note time - 08.31	1st t - 11.41	2nd t - 15.45	only if break	only if multiple

APPENDIX H: PARTICIPANT "MOST VALUABLE" COMMENTS

What is the most valuable part of today's training with MATT?
Now, I'm thinking about this situation as if it were real.
Actually putting the tourniquet on an amputated leg
The different situations I was put in…
New learning experience
Seeing the bleeding stop
Training broken down into steps
The realistic sounds and feeling of application of tourniquet
The best angle to apply the strap, it should be directly on the "high" artery
Realism
Having to actually stop the "bleeding"
Scenario with realistic sounds and light environment good training
Getting retraining/re-familiarize on the tourniquet
Having a mannequin that stopped squirting blood when you had the tourniquet on right
Tourniquet
Hands on
Hands on training with a moving mannequin helped prepare with real life scenario's
MATT itself
Opportunity to learn how to stop bleeding
Becoming more familiar with the CAT and learning its limitations
Refresher on the use of CAT
Hands-on practice applying a tnqt w/ immediate definitive feedback on how to tighten the tnqt other than verbalization
The movement of the MATT provided a real-life experience
Feedback after each scenario
The movement of the simulated amputee made training more realistic
N/A
Developing confidence in my skills with bleeding control
Tourniquet straps new to me
How tight the tourniquet was applied
N/A
N/A
Simulated bleeding and literally seeing if my tourniquet application was effective.
Applying the tourniquet through simulated battle situation which was very realistic
The night time training
Stress control

Night training
Hands on application of the CAT on the MATT -> very realistic
N/A
More realistic that what I have trained before
Hands on & practice
Remaining calm in an emergency

APPENDIX I: PARTICIPANT "LEAST VALUABLE" COMMENTS

What is the least valuable part of today's training with MATT?

N/A

Not a whole lot of instruction

No complaints

Can't really say at this time

Only the lower limbs were used

Initial instruction difficult to see, would have been better to circle everyone and demonstrate

Application of tourniquet without any verbal cues at beginning of each demo

I took a lot of valuable information from this training. Nothing was invaluable.

Wish there was a review before using MATT

The surrounds seemed too fake to make me motivated to hurry

N/A

Not realistic enough. If the training was a combat simulation, the training should have been done in combat gear, i.e. body armor, Kevlar, assault pack and gloves. Screaming or moaning from the MATT would make it more realistic.

I don't think any of it was least valuable I believe it was really valuable info.

Strobe light

Different bleeding parts

Strobe light is not realistic

Only legs were used

I don't think there was anything less valuable.

Limited to just the application of the tourniquet. Full treatment to MATT would make the training more realistic. It is hard for medical personnel to focus on only one part of patient care and just leave the rest undone. A team exercise may improve the experience and would also be more realistic.

Is not as realistic as performing on a live buddy

No variation in where to place the tnqt on which limb

N/A

None

A bit too easy since variable like body armor and other Soldiers were absent

N/A

I would prefer a full scenario possibly with a group.

The training hands on with the MATT should be prior to the scenario

N/A

N/A

N/A

The lack of smell and silence from the casualty.

More time should have been spent showing right and wrong ways to apply the tourniquet

The daytime training

Focusing on just tourniquet? Procedures on other types of injuries would be great at this standard or level

N/A

Waiting

The wait

Waiting

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