Examining the Effects of Stress on Tourniquet Application in a Layperson and Professional Civilian Population

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Abstract

Every year, approximately 3000 people die as the result of physical trauma in Sweden (Gedeborg, Chen, Thiblin, & Byberg, 2012). Many of these deaths occurs outside of the hospital and are preventable, including some caused by hemorrhage. One hemorrhage control device is the tourniquet which can be used in a civilian pre-hospital setting. The effects of stress on a laypersons tourniquet application ability is unknown and to date only one study have examined the effects of stress on tourniquet application in a military population (Schreckengaust, Littlejohn, & Zarow, 2014). The purpose of this study was to investigate how the performance of two first aid interventions, tourniquet application and cardiopulmonary resuscitation (CPR), is affected by stress in immediate (layperson) and first (professional) responders.

A total of 55 participants followed a brief educational program about hemorrhage control. Their ability to apply a tourniquet and perform CPR was tested in a calm classroom scenario and a stressful scenario, which consisted of paintball fire and an obstacle course. Stress was assessed through subjective reports of stress, physiological heart rate and heart rate variability measurements, and subjective workload and with a secondary task. The results showed differences of elicited stress reaction between the conditions and groups. Tourniquet and CPR performance was moderately affected by stress. Participants across all groups experienced more stress reactions during the stressful scenario, and laypersons did experience more stress reactions than professional first responders.

In conclusion, the method did make participants experience more stress reactions in terms of psychological, physiological and performance adaptations in the stressful scenario. However, the results need to be replicated and a list of suggested improvements are given, such as: examining the fidelity of the scenarios, validating the tourniquet application assessment method, and examining the relationship between tourniquet application performance and self-assessed performance.

Keywords: tourniquet, layperson, stress, hemorrhage control, workload

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Marc Friberg
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List of Abbreviations

Abbreviation	Meaning
ABC	Airway and cervical control, Breathing, and Circulation
ACS	American College of Surgeons
ATLS	Advanced Trauma Life Support
BATLS	Battlefield Advanced Trauma Life Support
CABC	Catastrophic hemorrhage, Airway and cervical control, Breathing, and Circulation
CAT	Combat Application Tourniquet
CMAST	Combat Medic Advanced Skills Training
CPR	Cardiopulmonary resuscitation
DHS	Department of Homeland Security
DSSQ	Dundee Stress State Questionnaire
EMS	Emergency medical services
EMT	Emergency and Military Tourniquet
HF	High Frequency
HR	Heart rate
HRV	Heart rate variability
JiT	Just-in-time
LF	Low Frequency
MRT	Multiple resource theory
NASA-TLX	NASA Task Load Index
NCEPOD	National Confidential Enquiry into Patient Outcome and Death
PSN	Parasympathetic nervous system
SBEC	Stop the Bleed Education Consortium
SNS	Sympathetic nervous system
SOFT-T	Special Operation Forces Tactical Tourniquet
STB	Stop the Bleed
TCCC	Tactical Combat Casualty Care

1 Introduction

"I am only one, but still I am one. I cannot do everything, but still I can do something.
And because I cannot do everything, I will not refuse to do the something that I can do."
- Edward Everett Hale

1.1 Background

Approximately 3000 people die every year as the results of physical trauma in Sweden (Gedeborg, Chen, Thiblin, and Byberg, 2012). In approximately 61% of these cases people deceases before arrival at the hospital. Amongst these deaths are so called preventable deaths, meaning that people could have survived if for example a bystander would have performed basic pre-hospital first aid actions before the arrival of health care professionals such as emergency medical services (EMS) personnel. Common complications resulting from physical trauma, with death as outcome, is airway obstruction, cardiac arrest and catastrophic bleeding (Evans et al., 2010). Airway management, along with cardiac arrest, is perhaps the two most common things to be covered in basic first aid training in schools: it is for example covered in the Swedish primary school curriculum Lgr11 since 2011 (Skolverket, 2011) and is also regularly taught at Swedish workplaces. Much less attention however is given to catastrophic bleeding treatment. Methods used in a civilian pre-hospital setting for catastrophic bleeding treatment, or hemorrhage control is applying direct pressure, preferably with a hemostatic agent, to the wound or by applying a tourniquet to a wounded extremity, depending on where the bleeding stems from (Achneck et al., 2010; Smith, Laird, Porter, & Bloch, 2012). If untreated, a catastrophic bleeding can result in exsanguination in a couple minutes from the onset of the bleeding (Harris & Noble, 2009). This, of course, means that it is crucial that a patient receives quick and adequate treatment directly if a catastrophic bleeding would appear. In Swedish municipalities, the average time to arrival of EMS personnel from the initial emergency 112 phone call is 10-30 minutes (Sveriges kommuner och Landsting, 2018). Thus, one cannot always rely on professional help and it is therefore necessary to teach hemorrhage control to the public.

In 2015 the White House initiated the Hartford Consensus and the Stop the bleed (STB) program, a concept, which aims to educate the public in hemorrhage control due to numerous antagonistic events such as school shootings and triggering of explosive devices in public places. The concept and initiative is based on the work from the American Department of

Homeland Security (DHS) and American College of Surgeons (ACS) along with representatives from a wide range of areas such as healthcare, authorities, emergency personnel and the military. The Hartford Consensus described the public as a group of people who would likely be immediate responders on the scene of an accident and would therefore be a crucial group to educate on the matter.

In the Hartford Consensus compendium (Hoyt et al., 2015) direct pressure, along with two types of devices, are recommended for hemorrhage control: tourniquets and hemostatic dressings. The tourniquet is a device which is placed and tightened around an external wounded limb in order to create circumferential pressure to stop a catastrophic bleeding (Walters et al., 2009). Much of today's knowledge about tourniquet usage comes from the military, since tourniquets have been extensively used in combat settings (Kragh & Dubick, 2016). Tourniquets usage have been disregarded in civilian pre-hospital settings by many in fear of complications such as limb ischeamia and reperfusion injuries, and it has been argued that battlefield injuries differs significantly compared to injuries in a civilian setting (Scerbo et al., 2016). However, growing evidence shows that tourniquet usage is an effective method to stop catastrophic bleeding and reduces mortality in pre-hospital settings without major complications to the wounded patient (Beaucreux, Vivien, Miles, Ausset, & Pasquier, 2018; Teixeira et al., 2018). It is acknowledged in the literature that combat settings differs from civilian settings in many obvious ways, but since much research have been conducted and data been collected from the military, it is very likely that the knowledge acquired from the battlefield can be translated to a civilian pre-hospital setting with great benefits (Kauvar, Dubick, Walters, & Kragh, 2018; Ode, Studnek, Seymour, Bosse, & Hsu, 2015). Since tourniquet usage seems to be an effective method in pre-hospital hemorrhage control (Leonard et al., 2016; Scerbo et al., 2017; Teixeira et al., 2018) research have been made to study how a layperson can learn hemorrhage control. Several studies have shown that shorter interventional education programs possibly can be enough to learn a layperson to apply a tourniquet, as well as increase the willingness to act when encountering a wounded individual with a catastrophic bleeding (Goolsby, Branting, Chen, Mack, & Olsen, 2015; Goolsby, Strauss-Riggs, et al., 2018; Hegvik, Spilman, Olson, Gilchrist, & Sidwell, 2017; Jacobs & Burns, 2015; Sidwell, Spilman, Huntsman, & Pelaez, 2018). The results seems promising on their own, but due to lack of general guidelines how an educational program should look like, the results are hard to generalize and compare (Ramly, Runyan, & King, 2016). It is not until recently that such guidelines is starting to exist as shown by Goolsby, Jacobs, et al. (2018).

This is important, but one of the major limitations in the current literature and in current educational programs is the lacking aspect of how stress affects tourniquet application performance. A likely hypothesis is that if a laypersons is the immediate responder at a scene of an accident, he or she will be stressed, and that will affect the person's ability to apply a tourniquet (Goolsby, Strauss-Riggs, et al., 2018). Hence, this is one of the motivations behind the forming of the hypotheses. The effects of stress and tourniquet application has previously only been examined in one study by Schreckengaust, Littlejohn and Zarow (2014), in which they tested tourniquet application ability during calm and stressful circumstances in a military population. Their results showed that tourniquet application performance decreased during stressful circumstances compared to calm circumstances, hence this is another motivation behind the hypotheses. In their article Schreckengaust, Littlejohn and Zarow (2014) claim that they exposed the participants to stress, without actually validating that the participants were or felt stressed, which, according to several current frameworks in stress research, must be done (Hancock & Warm, 1989; Hockey, 1997; Lazarus & Folkman, 1984; Matthews, 2001). This serves as the final motivation for the hypotheses. In order to close this gap in the literature, how a laypersons ability to apply a tourniquet is affected by stress, this study's purpose and hypotheses follow below.

1.2 Purpose and Hypotheses

The purpose of this study is to investigate how the performance of two first aid interventions, tourniquet application and CPR, is affected by stress in immediate (layperson) and first (professional) responders. From this purpose, the following four null hypotheses, with associated alternative hypotheses, were formed and are tested in this study:

- **H_01**: Tourniquet and CPR performance will be equal during the stressful scenario and the calm scenario across all groups.
- **H_11**: Tourniquet and CPR performance will be lower during the stressful scenario compared to the calm scenario across all groups.
- **H_02**: Laypersons tourniquet application and CPR performance will be equal to the performance of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.
- **H_12**: Laypersons tourniquet application and CPR performance will be lower than that of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.

- **$H_0 3$**: Participants across all groups will not experience more stress reactions during the stressful scenario compared to the calm scenario.
- **$H_1 3$**: Participants across all groups will experience more stress reactions during the stressful scenario compared to the calm scenario.
- **$H_0 4$**: Laypersons will not experience more stress reactions than professional first responders during both the calm and stressful scenario.
- **$H_1 4$**: Laypersons will experience more stress reactions than professional first responders during both the calm and stressful scenario.

1.3 Limitations and Demarcations

The tourniquet used in this thesis is the Combat Application Tourniquet (generation 7). This is only one of many types of commercially available tourniquets and as such should be considered a limitation. The tourniquet assessment template is also used only to assess Combat Application Tourniquet performance. This is one of many assessment methods.

The study examines the effects of one educational program. It is not safe to say that all educational hemorrhage control programs would have the same effect as shown in this study.

Other limitations include the method used to capture physiological reactions in the participants. Measuring heart rate and heart rate variability with a commercially available heart rate monitor is a cheap, relatively non-intrusive and easy to use method, and other physiological measurements are not included in this study.

2 Theory

This chapter will present theory about hemorrhage and hemorrhage control, tourniquet usage in a civilian population, tourniquet training for laypersons, and finally, stress and mental workload.

2.1 Hemorrhage and Hemorrhage Control

A Swedish study showed that approximately 3000 people die every year due to trauma, out of which 61% dies before arrival at the hospital (Gedeborg et al., 2012). Many of which cases involves catastrophic bleeding. A study have showed that globally, hemorrhage is the cause of 30-40% trauma mortality and 33-56% out of these deaths occurs before arrival at a hospital (Kauvar, Lefering, & Wade, 2006). In a military setting these numbers stretches even further, with a reported mortality rate as high as 80% in cases with potential survivability (Eastridge et al., 2011). This strengthens the case for further research in the area of pre-hospital hemorrhage control.

Severe trauma can cause a catastrophic bleeding which can, if untreated, cause hypovolemia. Hypovolemia is a state of decreased blood volume which eventually lead to hemorrhagic shock which is a form of hypovolemic shock caused by blood loss. More specifically: the oxygen delivery for aerobic metabolism does not meet the oxygen demand and if the catastrophic bleeding goes further untreated it will eventually lead to the worst case scenario: death (Barbee, Reynolds, & Ward, 2010; Cannon, 2018). In the United Kingdom's civilian population, the National Confidential Enquiry into Patient Outcome and Death (NCEPOD, 2007) identified early hemorrhage control as maybe the single most important step in the chain of survival after a trauma incident. According to Cannon (2018) evidence shows that the initial steps to take to prevent fatality, or any further damage to the body after a trauma followed by a catastrophic bleeding, is to identify the source of bleeding and minimize further blood loss before definite hemostasis can be achieved. Hemostasis, the process to stop a bleeding, is generally considered a complex process and in cases with severe trauma, hemostasis cannot be achieved until the patient receives professional advanced trauma care, preferable at a hospital (Cannon, 2018).

As mentioned, evidence shows that the external peripheral hemorrhage is the leading cause of combat casualty, hence rapid hemorrhage control techniques is crucial (Hodgetts, Mahoney, Russell, & Byers, 2006; Lee, Porter, & Hodgetts, 2007). In the 1990s the Advanced

Trauma Life Support (ATLS) protocol by the American College of Surgeons (ACS) have become the gold standard in European countries of acute trauma care (Stahel, Heyde, Wyrwich, & Ertel, 2005). One of the most widely known principles of the ATLS protocol is the ABC mnemonic (in its variations, ABCD, ABCDE and ABCDEF) for in which order trauma complications should be addressed: Airway and cervical control, Breathing, and Circulation. But with recent research showing that hemorrhage is the leading cause of combat casualty, a newer revised variations of the ABC algorithm is advocated in the Battlefield Advanced Trauma Life Support (BATLS) and the Tactical Combat Casualty Care (TCCC) (Butler, 2010): CABC, which stands for Catastrophic hemorrhage, Airway and cervical control, Breathing, and Circulation, indicating that catastrophic hemorrhage should be prioritized first (Hodgetts et al., 2006). It is acknowledged in the literature that combat settings differs from a civilian setting in many obvious ways, but much research and data on hemorrhage control in military settings is available and it is very much possible that the knowledge gained from military settings can be transferred to a pre-hospital civilian context (Kauvar et al., 2018; Ode et al., 2015).

In the Hartford Consensus compendium (Hoyt et al., 2015) directed pressure, along with two types of devices are recommended for hemorrhage control: hemostatic dressings and tourniquets. A hemostatic dressing is a dressing which contains antihemorrhagic substances (i.e. substances which promotes hemostasis) which is applied directly on a wound preferably with direct pressure (Granville-Chapman, Jacobs, & Midwinter, 2011). Hemostatic dressings are typically used together with tourniquets but can be applied to all areas of the body, whereas tourniquets on the other hand only can be applied to the extremities (Cannon, 2018; Granville-Chapman et al., 2011; Smith et al., 2012). Although hemostatic dressing can be applied to all areas of the body, including the extremities, and are recommended in the Hartford Consensus compendium (Hoyt et al., 2015), they are considered to be expensive and there is little evidence showing that they are easy to use for a layperson, and that applying direct pressure constantly is not always a possible practical solution (Goolsby, Jacobs, et al., 2018).

The second device recommended for hemorrhage control in the Hartford Consensus compendium is the tourniquet. A tourniquet is a device that is applied proximal to a wound on a limb creating indirect pressure. The purpose of the design of the tourniquet is to create enough circumferential compression on the wounded limb to the point that the arterial flow ceases enough to stop a bleeding (Walters et al., 2009). There are many commercially

available tourniquets such as the Combat Application Tourniquet (CAT), Special Operation Forces Tactical Tourniquet (SOFT-T) and Emergency and Military Tourniquet (EMT) many of which is designed to be applicable with one hand in cases where the injured must be able to applicate the tourniquet by himself (Walters et al., 2009). A tourniquet however must not be of commercial type but can also be improvised, such as using a piece of cloth along with a stick (Stewart, Duchesne, & Khan, 2015).

Results from a retrospective analysis of data from the U.S National Emergency Medical Services Information System between 2011 and 2014 showed that reported cases of tourniquet usage significantly increased from 138 in 2011 to 701 in 2014, showing the popularity of tourniquet usage. This however has not always been the case. The use of tourniquets have been subject for debate for a long time and have in extreme cases been described as "an invention of the Evil one" (Blackwood, 2001). Over the years tourniquet usage have been disregarded due to its association with many complications and issues, and in a review article by Lee, Porter and Hodgetts (2007) they list several of those complications such as: limb ischeamia, reperfusion injuries, increased bleeding from soft tissue injuries or damaged arteries when a tourniquet is applied incorrectly, or severe pain in the patient on which the tourniquet is applied. Although there has been an aversion to use tourniquets in pre-hospital settings, both when used by civilians or professional health care personnel, few studies actually shows complications possibly due to tourniquet usage (Beaucreux et al., 2018). Although many of the listed complications are held to be true and relevant, one must consider when the pros of tourniquet usage outweighs the cons all depending on which context the tourniquet is used in (Kauvar et al., 2018; Kragh, Swan, Smith, Mabry, & Blackbourne, 2012; Navein, Coupland, & Dunn, 2003). Factors such as time, resources and the condition and numbers of injured will affect the ability and incentive to use a tourniquet and in extreme cases, such as being alone in the wilderness, a tourniquet is no longer a "last resort" but rather an *only* resort (Navein et al., 2003). One of the major reasons for the tourniquets extensive use in combats settings is the speed of which the tourniquet can be applied. Although the tourniquet is mostly design to be quickly applicable "under fire" there are many situations in the civilian life were a tourniquet can be of great use. Lee et al., (2007) posts a number of realistic scenarios when a tourniquet can be applicable: penetrating trauma from firearms and stabbings, police officers working in tactical environments, terrorist attacks, settings with limited resources (wilderness or places with few or any hospitals nearby) and industrial accidents. This goes to show that there is a real need for teaching the public how to handle

catastrophic hemorrhage. The STB campaign might have been started with terrorist acts and public shootings in mind, but bleeding control is essential in many other scenarios as well.

2.2   Pre-Hospital Usage of Tourniquets

In order to determine if tourniquets actually is applicable and effective in a civilian setting, several studies have been made regarding the matter. Beaucreux et al. (2018) conducted a retrospective literature review, with 24 studies included with 22 of the studies published 2014 or later, about tourniquet usage in a civilian setting. They noted that possible complications due to tourniquet usage was reported in only one of the 24 studies which indicate that the aversion to tourniquet usage may be misguided mainly due to older literature being based on tourniquet usage in combat settings. In another literature review recently published by Teixeira et al. (2018) data was retrospectively gathered and analyzed for six years from 11 Level 1 trauma centers in the US. A total of 1026 patients with peripheral vascular injuries were included and the 181 reported cases of pre-hospital tourniquet usage was found. The results showed that tourniquet usage was associated with a 6-folded mortality reduction, without any increased risk for amputation. Although Teixeira et al. (2018) found that tourniquet usage was independently associated with mortality reduction they do acknowledge other factors such as the use of hemostatic dressings as something that can be a contributing factor to the decreased mortality. However, they do conclude with and emphasize "a more aggressive pre-hospital approach to the application of extremity tourniquets in civilian trauma patients with extremity hemorrhage and traumatic amputation" (Teixeira et al., 2018, p. 7). Two other large-scale retrospective analysis have also shown the efficiency of pre-hospital tourniquet usage. Leonard et al. (2016) examined data gathered between 2009 and 2014 about the use of the hemostatic dressing QuikClot and the Combat Application Tourniquet (CAT) with a total number of 95 observed uses. The results showed that in 98% of the cases (n=61) the CAT hemorrhage control could be achieved, in comparison to the QuikClot effectiveness of 89% (n=40). Morbidity was observed in 18% and 12.5% of the cases for CAT and QuikClot respectively, but Leonard et al. (2016) suggests that the severity of the injury rather than tourniquet usage might be the cause of death, and in compliance with Teixeira et al. (2018) they suggest a more widespread use of the tourniquet as a means to achieving hemorrhage control in a pre-hospital civilian setting. Scerbo et al. (2017), who also conducted a retrospective review study, found results similar to the above-mentioned articles. Scerbo et al. (2017) analyzed data from a Level 1 trauma center in Texas, US, with a total

number of 306 reported instances of tourniquet usage, 252 instances of tourniquet applications that were made in pre-hospital settings and 29 instances of tourniquets applied at the trauma center. Results from the study indicates that waiting to arrival at the hospital before applying a tourniquet was associated with lower blood pressure upon arrival, more plasma transfusions, a higher rate of transfusion within the first hour of arrival and an increased risk of death from hemorrhagic shock. One of the major limitations of all the studies mentioned above was that they were retrospectively done. Examining morbidity causes is highly complex and there are usually many factors, which are hard to isolate, that in the end can cause morbidity. This is acknowledged but nevertheless tourniquets are highly recommended for pre-hospital use (Beaucreux et al., 2018; Leonard et al., 2016; Scerbo et al., 2017; Teixeira et al., 2018).

2.3 Tourniquet Training for Laypersons

It is highlighted in the Hartford Consensus compendium that there is a need for large educational tourniquet training programs for the civilian population, but as pointed out by Goolsby, Jacobs, et al. (2018), it is not explicitly stated how this should or could be done in practice. Goolsby, Jacobs, et al. (2018) recognize that there are no general guidelines about the content, content delivery mechanism or how the effectiveness of a STB course could be measured. As acknowledged by Goolsby, Jacobs, et al. (2018) a "one-size-fits-all" approach are likely to fail for the obvious reason that some people require more or less training than others based on previous medical experience and knowledge, hence they suggests tiered training. Based on work by the Stop the Bleed Education Consortium (SBEC), which is a group of experienced medical personnel, they have identified three different target subgroups for training based on prior health care experience and knowledge: layperson, trained layperson and health care professionals. The SBEC's definition of each target groups is as follow:

The layperson is described as someone with no medical knowledge and a lesser likelihood of using educational material or enrolling in any educational program. The experienced layperson is described as someone with additional need or motivation to be trained in bleeding control. These people are somewhat more likely to use any medical competence they have in their employment, such as policemen or industrial workers. The health care professional tier is as the name suggests, people whose profession is in the medical field, such as Medical Doctors or personnel in the emergency medical services. These people are highly experienced and need highly advanced training for further improvement. Each of these groups comes with their own needs and constraints when it comes to education and

motivation. What is beneficial for one group might be useless for another, hence education should be adapted to the meet the needs for each specific group (Goolsby, Jacobs, et al., 2018).

Goolsby, Jacobs, et al. (2018) recommends that a STB training curriculum should address three learning domains based on the work of Bastable, Gramet, Jacobs and Sopczyk, (2011): cognitive (knowledge), psychomotor (skills) and affective (attitudes). Within these three domains Goolsby, Jacobs, et al. (2018) states that a STB education programs should achieve the following for laypersons:

1. Motivate learners to act when faced with a hemorrhagic emergency (affective domain).
2. Teach learners to distinguish life-threatening from non – life-threatening bleeding (cognitive domain).
3. Teach learners to apply pressure (cognitive and psychomotor domains).

The first point (1) deals with the problem of how to motivate laypersons to act when they are the first responder at a scene of accident. In CPR education, it have been shown that an individual's self-assed knowledge or skills can be associated with the motivation and willingness to act in an emergency situation (Nord, 2017), hence it is important that an educational program spurs the motivation in the layperson. In tourniquet training however, studies have found a confidence-competence mismatch among individuals, meaning that high confidence in tourniquet application does not equal high competence in actually applying a tourniquet (Baruch et al., 2017; Kragh et al., 2011). This means that although it is important that a layperson feels confident and willing to act in an emergency situation, and an educational program should evoke this feeling, the program must be validated so that it is certain that the educational program actually teaches proper tourniquet usage. This lesson learned is extra important amongst laypersons since numerous studies have shown that novices tends to be over-confident in newly acquired skills (Dunning, Heath, & Suls, 2004). The second point (2) deals with the problem of how to teach laypersons how to distinguish a life threatening from a non-life-threatening bleeding. Goolsby, Jacobs, et al. (2018) suggest keeping this point very simple for laypersons. The volume and flow of the blood are the only two points that should be discussed, and more information could cause confusion since it is very unlikely that a layperson had been exposed to any life-threatening bleedings previously. Goolsby, Jacobs, et al. (2018) recommends that if the blood volume from the bleeding exceeds half the volume of a soda can (150 ml) or the blood flow is continuous and steady the

bleeding is to be considered life-threatening. The third (3) point is the most crucial point since it deals with the one thing that actually stops a catastrophic bleeding: learning how to apply pressure to a wound. Following point (1) and (2) the program must be short and captivating in order to motivate the layperson to act, as well as teaching how to distinguish a life-threatening from a non-life-threatening bleeding. This takes time from the last point (3), giving the layperson less time to actually learn how to practically stop a bleeding using a hemostatic dressing or a tourniquet.

Previous studies of layperson training have shown scattered results. Hegvik, Spilman, Olson, Gilchrist and Sidwell (2017) examined the effect of an eight minute long educational module about hemorrhage control for medically trained personnel and laypersons (approximately one-third of the participants non-clinically educated personnel) at a Level 1 trauma center in the US (n=4845) were they used a pre- and posttest multiple choice questionnaire to asses knowledge about hemorrhage control techniques and response procedures. The pretest went from 57% correctly answered questions to 98% correctly answer questions in the posttest.

In a similar study by Jacobs and Burns (2015) both clinical (n=53) and nonclinical personnel (n=169) at the Hartford Hospital in Hartford, US were exposed to an intervention consisting of either a live demonstration of tourniquet application or a 3-minute video demonstration followed by practical training for about approximately 15 minutes in total. Performance measures were component such as: stating indications for tourniquet usage, describing steps to apply a tourniquet, identifying if the tourniquet is successfully applied and demonstrating a correctly applied tourniquet. Participants also rated their level of confidence for five aspects of tourniquet applications on a 5-point Likert-type scale. Both confidence score and the performance measures were tested pre- and post-intervention. The results showed that for both groups, clinical and non-clinical personnel, confidence scores were significantly higher after the intervention compared to before. The group who received live demonstration reported a significantly higher confidence at the post-test compared to the group who received the video demonstration. Although the overall highest scores were reported by the clinical personnel receiving live demonstration the authors conclude that a brief demonstration, live or on video and clinical or non-clinical personnel is linked to a higher confidence score on applying a tourniquet (Jacobs & Burns, 2015).

In a third study 729 employees, both clinical and non-clinical personnel (approximately 40% non-clinical personnel), at four hospitals in a mid-sized metropolitan area in an

American city took part of a study were the were exposed to a brief six to ten minutes long practical hands-on training course about bleeding control (Sidwell et al., 2018). A pre- and post-intervention questionnaire were used, where participants rated on a 5-point Likert-type scale the likelihood that they would: take action if they were the only person available to assist a bleeding victim, correctly apply pressure to control a bleeding, and applying a tourniquet to a bleeding victim. The results showed a significant increase in likelihood for all three questions at the posttest questionnaire regardless of clinical experience. For non-clinical personnel (n=251), 76% of the participants reported that they would likely assist a bleeding victim before the training. This number were raised to 95% after the training. The likelihood of correctly applying pressure or applying a tourniquet was reported by slightly above 50% of the participants before training but was raised to 95% after the training (Sidwell et al., 2018). These results shows the same pattern as the study by Jacobs and Burns (2015), indicating that shorter training sessions have a deep impact on laypersons training.

Goolsby, Branting, Chen, Mack and Olsen (2015) have previously conducted a study were participants (n=194) with no military or medical experience received either just-in-time (JiT) instructions or no instruction for tourniquet application. The primary outcome measure was successfully application of a CAT, and secondary outcome measures were time for successfully applying the CAT, reasons for failed tourniquet application, and, pre- and posttest questions were asked about participants willingness and comfort using a tourniquet a real-life setting. The analysis discovered, maybe not so shockingly that JiT more than doubled successful tourniquet application compared to no instruction. 44% of the participants that received JiT instructions (n=145) successfully applied the tourniquet, whereas 20% of the participants receiving no instruction (n=49) successfully applied the tourniquet. Goolsby, Strauss-Riggs, et al. (2018) later on build upon the previous mentioned study and expanded the work by comparing a control group of participants receiving only JiT during the test (n=131) or receiving web instructions (roughly <15 minutes of material) 4 to 8 weeks prior to the test scenario as well as receiving JiT during the test (n=95). Outcome measures were the same as in Goolsby et al. (2015) with the addition of testing the participants ability to distinguish a bleeding requiring a tourniquet from a bleeding requiring direct pressure only, as well as marking the tourniquet placement position. For the group receiving no prior web education but JiT the tourniquet application success rate was 50%, whereas for the group receiving web education and JiT the success rate was 75%. For willingness to act ("Yes, I would use a tourniquet in real life"), pre-scores went from 60% to 79% in total for all

participants (p < .05) and for comfort level of using a tourniquet in real life (comfortable or very comfortable) scores went from 22% to 47% in total for all participants. Goolsby, Strauss-Riggs, et al. (2018) describes their findings to be in line with modern learning theory (Knowles, Holton, & Swanson, 2015). Receiving JiT while learning a new skill greatly benefits learning, just as shown in the previous study by Goolsby et al. (2015). JiT along with preexposure to the material boosts learning even more as shown by the success application rates. Goolsby, Strauss-Riggs, et al. (2018) also mention that willingness to act and comfortability to applying a tourniquet in a real life scenario are key predictors for a layperson to actually respond during a crisis, this they mention have also be shown in other related work of willingness to act in public crisis such as flu pandemics (Barnett et al., 2009) or environmental disasters, radiological events, and mass casualty events (Qureshi et al., 2005).

Although shorter educational programs about bleeding control have shown promising results, given all of the mentioned research above, there are limitations to this. As mentioned in the article by Baruch et al. (2017) they did discovered a confidence-competence mismatch between confidence of applying a tourniquet and actual tourniquet application performance. This shows that a subjective report of willingness to act not necessary ensures that a layperson can apply a tourniquet in a real-life scenario. Thus, given the three points of what an educational program for laypersons should include by Goolsby, Jacobs, et al. (2018), (1) motivating learners to act when faced with a hemorrhage emergency, (2) teach learners to distinguish life-threatening from non-life-threatening bleeding, and (3), teach learners to apply pressure, just motivating laypersons to act and boost their confidence and willingness to act, (1), is not enough. Actual performance must be ascertained in a STB program. As for point (2), few studies explicitly tested laypersons ability to distinguish a life-threatening for a non-life-threatening bleeding (Goolsby, Strauss-Riggs, et al., 2018; Jacobs & Burns, 2015). The last point (3) were the main focus for all studies and it is here were the matter becomes complicated. The lack of standardized (pedagogic) guidelines for how a bleeding control or STB program should look like have made it difficult to evaluate current educational programs (Ramly et al., 2016) but with the recent work by Goolsby, Jacobs, et al. (2018) this problem will hopefully eventually fade away.

In all studies described so far, all tests are conducted in a calm classroom setting, with bleeding simulated with different methods such as: a piece of tape on a lower-body mannequin (Goolsby et al., 2015; Goolsby, Strauss-Riggs, et al., 2018), a hemorrhage control training leg (Sidwell et al., 2018) or a real person laying "wounded" flat on the floor (Jacobs

& Burns, 2015). In simulation-based training, one of the most important concepts are "transfer of training". The goal of training is, of course, not the training itself but how the learned training actually transfers to a real-world setting (Hancock, Vincenzi, Wise, & Mouloua, 2008). In simulation-based training the goals are to create a simulation so that the transfer of training effect is maximized. One of the factors affecting the transfer of training effect is fidelity. Fidelity is defined as the extent to which the simulations replicates the actual environment (Hancock et al., 2008). In simulation theory, fidelity is typically divided into different types of fidelity, each touching different aspects of the simulation such as: physical fidelity, equipment fidelity, task fidelity and psychological or cognitive fidelity (Hancock et al., 2008). Without going into any further depth about this matter it is safe to say the previously mentioned simulation types (Goolsby et al., 2015; Goolsby, Strauss-Riggs, et al., 2018; Jacobs & Burns, 2015; Sidwell et al., 2018) all are low fidelity simulations which in itself is not bad; Alessi (1988) proposed the "Alessi Hypothesis" were he states that for novices low fidelity simulations are preferred during the initial learning since they would not benefit from high fidelity simulations since high fidelity increases complexity which leads to an increase workload for the novice, making them overwhelmed. As acknowledged in the study by Goolsby, Strauss-Riggs, et al. (2018), they simulated a catastrophic bleeding on a static leg model, without the visual, auditory and emotional stress that is typically associated with treating trauma victims with life-threatening injuries. In order to validate their current educational approach further testing on laypersons ability to perform under stress must be examined.

   To this date, the only study that has examined tourniquet application performance and stress is by Schreckengaust et al. (2014) who tested the ability to apply a tourniquet under calm and stressful settings in a military population. Schreckengaust et als. (2014) incentive to their study was that although the conceptual simplicity of a tourniquet, the failure rate (with casualty as outcome) for the CAT was as high as 21% (and 34% for the SOFT-T) in battlefield settings (Kragh et al., 2008). Given that studies have reported high success rates on tourniquet application in civilian pre-hospital and classroom training, Schreckengaust et al. (2014) hypothesized that it is the stressful nature of the combat environment that causes low successful rates of tourniquet application at the battlefield. In Schreckengaust et als. (2014) study, they tested 89 U.S. Navy Hospital Corpsmen's tourniquet application ability during a 5-day TCCC course. During day 1 a pre-test on tourniquet application was conducted in a classroom setting (low stress scenario), followed by two days of training and at day 4 their

tourniquet application ability was tested, once again in a classroom setting. At day 5, the participants completed a simulated combat obstacle course (high stress scenario) in pairs of two, fully geared in Kevlar vests, helmets, face and eye protection and dummy weapons. The obstacle course consisted of five stations which the participants ran between through a wooded area with water and mud, leap frogging between covers whilst giving each other suppressive fire. During the obstacle course they were under paintball fire as well. Two of the stations consisted of tourniquet application (CAT and SOFT-T), in which a person was lying on the ground expressing discomfort to "add to distraction and *stress"* (Schreckengaust et al., 2014, p. 116, own emphasis). Outcome measures for the tourniquet application was: placement accuracy, time to application and elimination of pulse. The results showed that placement accuracy increased from day 1 to day 4 for both the CAT and SOFT-T, then declined at the simulated combat scenario. Time to application significantly decreased from day 1 to day 4 for both tourniquet types, indicating a training effect, but then significantly increased at the simulated combat scenario. The elimination of pulse variable showed a similar pattern, pulse elimination improved from day 1 to day 4 for both tourniquet types, then yet again declined during the simulated combat scenario. Schreckengaust et al. (2014) claimed that simulated combat scenario was highly stressful, but this is not necessarily true since they 1) did not measure any physiological markers for stress such as heart rate variability or cortisol level, and 2) did not measure any subjective reporting of stress. It is then unclear whether the decline in tourniquet application performance was the effect of stress, which it very well could be, or if it is because of the mere fact that the participants were physically exhausted from the obstacle course. It is not enough to say that something is a stressor for it to actually *be* a stressor. This is a motivation to reproduce the study by Schreckengaust et al. (2014) but also include physiological and subjective measurements of stress.

2.4   Stress

In the following section the concept of stress will be discussed generally and how it relates to the current research question: how a laypersons ability to apply a tourniquet is affected by stress.

Jones, Bright, and Clow (2001) describes how stress historically have been interchangeably used and inadequately differentiated from terms such as strain, pressure, demand and stressors, which caused the research area to be propagated with literature where there was no clear consensus of what stress is and how to measure it. (Jones et al., 2001)

writes that because the various definitions of stress have been so vague researchers have considered an approach where stress is not seen as a variable but rather as Lazarus and Folkman (1984, p. 10) expresses it as a: "rubric consisting of many variables and processes'".

According to Jones et al. (2001) early researched used a simple input-output approach to study stress. While this was moderately a successful approach it governed inconclusive results since it could not account for individual factors that could affect the outcome for an input. Cox (1993) explains that at the time, three different approaches were used to study stress. The first approach is the engineering model – which is somewhat comparable to an input-output model of stress where stress is treated as stimulus characteristic of the person's environment. Methodologically, this would mean that stress is an "objectively measurable aspect of the environment" (Cox, 1993, p. 9). The second approach is the physiological model, where stress is defined based upon the physiological or biological changes during stressful events (Mark & Smith, 2008). The last approach, and the maybe the most prominently, is the psychological approach which generally is divided into two different approaches in itself: the *interactional* approach and the *transactional* approach (Cox & Griffiths, 2005). The interactional approach focusses on the structural characteristics of stress, i.e. how will a certain stressor affect a given population (Mark & Smith, 2008). Jones et al. (2001) describes three types of measures typically used in interactional approaches: environmental events or situations (i.e. stressors), intervening variables (i.e. personality traits) and strain outcomes (i.e. physical responses). Even though self-reported measures of stress is used in this approach, subjects might report how a certain life event such as a break up causes stress, a lacking component in this approach is the lack of cognitive evaluation of stressors – such as *how* stressful the break up was (Jones et al., 2001). Some proponents of this approach (see for example Fletcher, 1999) suggests that this cognitive evaluation of stressors is not necessary, as Jones et al. (2001, p. 19) puts it: "a subject does not need to perceive a stressor as unpleasant or stressful for it to have a negative effect". However, it is for this very reason the interactional approach has been criticized by researchers suggesting the transactional approach, where on the currently influential theories is the *appraisal theory of stress* by Lazarus and Folkman (1984). As discussed in Lazarus, DeLongis, Folkman and Gruen (1985) stress have been treated in the literature both as an independent variable, as well as a dependent variable. They acknowledge the problem of conceptualizing stress as something caused by the environment as well as conceptualizing it as an effect of the environment. They argue however that stress is more of a relationship between the person and the environment as perceived and appraised by that person, ergo, the

two components are considered inseparable. This essentially means that the concept of stress must be examined from multiple angles. One cannot for example study stress by only measuring external stressors without measuring any mental processing happening inside the person being affected by said stressors. According to Lazarus and Folkmans (1984) theory how an individual respond to stress is determined by how the individual subjectively appraises stressors created in the environment. This process is divided into two parts: primary and secondary appraisal. Primary appraisal is when the individual determines whether a stressor poses a threat or not, and secondary appraisal is the individual's assessment whether (s)he has any disposable mental resources, strategies or coping abilities to handle the stressors (Lazarus & Folkman, 1984). It is important to highlight that Lazarus and Folkman (1984) also includes the concept of re-appraisal in their theory; they state that appraisal is a constantly ongoing process, and not a static process. Not only does an individual evaluate his or her relation to the external environment, the individual also re-evaluates the relation, as time goes by. For example, if an individual encounters a bleeding victim on the ground the initial response from the individual might be to run away in panic, but after continuously re-evaluating the situation the individual remembers his hemorrhage control training and grabs a tourniquet from his backpack and starts applying it to the wounded victim.

As described by Matthews (2001), transaction theory states that stress outcomes in an individual are related to appraisal of the environmental demands and the person's choice of coping strategy. Lazarus and Folkman (1984) means that there are two categories of processing: problem or tasked focused and emotion focused processing. The two types of processing uses two types of coping mechanisms: problem or task focused coping is directed toward changing external reality (i.e. physically moving away from an external threat), whereas emotions focused coping is when internal feelings or thought patterns are changed (i.e. convincing yourself that you are happy when you are in fact sad). Coping in turn, overlaps with the concept of self-regulation, more specifically: stress reactions are controlled by self-regulative processing constructs (Matthews, 2001). In earlier work by Wells and Matthews (1994) they suggest that a self-regulatory process is organized at three levels: a lower automatic level, an executive level, and a schema-like self-knowledge in long-term memory. This view shares resemblance with the view from classical theory of cognitive science (i.e. Newell, 1980; Pylyshyn, 1984) were cognitive processes are described using levels of explanation. Matthews (2001) have adopted this view, along with Lazarus and Folkmans (1984) transactional theory, into the stress area and suggest a framework were the

transaction between the individual and the environment can take place at three levels: the physiological, the computational, and the goal-directed level. The idea is that the effects of stress factors (i.e environmental variables) provokes different stress response, or *states*, that depends on the different appraisal and coping mechanisms; the states themselves influences multiple information-processing components (mediated between the three levels), which in turn evokes different behavioral outcomes (Matthews, 2001). As such, a stressor can evoke different reactions, and are classified accordingly as either affecting the physical body of the individual (e.g. by increasing or decreasing body temperature), or affecting the cognitive or computational functions (e.g. increased or decreased mental workload), or affecting the individual's observed behavior (e.g. reduced or increased performance), or affecting all or some of the levels at the same time (Matthews, 2001). In this framework one could therefore explain the same phenomena using different levels of explanation, depending on what research questions being asked.

Furthermore, Matthews (2001) argues that stress is a multidimensional construct consisting of three factors: task engagement, distress and worry. These three constructs themselves can be divided into 11 cognitive and emotional dimensions such as: concentration, energetic, arousal, motivation, self-esteem etc. In order to measure the three factors, including the 11 dimensions, the Dundee Stress State Questionnaire (DSSQ) was created (Matthews, Campbell, Falconer, & Gilliland, 2002; Matthews et al., 1999). The DSSQ assess subjective reports of an individual's mental stress states across the three factors. Task engagement is related to task-focused coping and involves state constructs about task interest and focus; distress is related to emotion-focused coping and integrates states about unpleasant moods and tension with lack of confidence and perceived control; worry is also related to emotion-focused coping, as well as avoidance coping and involves states about self-focused attention, self-esteem and cognitive interference resulting from both the task at hand, as well as individual concerns (Matthews, Campbell, Falconer, & Gilliland, 2002; Matthews et al., 1999).

Hancock and Warm (1989) on the other hand have taken a slightly different approach to the stress concept and have proposed a *dynamic model of stress*, where they view stress a dynamic relationship described by "*The trinity of stress*" which consists of: the physical environment (which is deterministic), the adaptive or compensatory processes in the individual (which is nomothetic and depends of the strategies of the bodily structure), and the output of the individual (which is idiographic and is dependent on the individual). All three

foci can be used to explain responses at multiple levels, both in the physiological and behavioral domain (Hancock & Warm, 1989). In their article, Hancock and Warm (1989) describes three modes of operation in a system: one in which the dynamic stability prevails, one in which dynamic instability occurs and ultimately leads to the collapse of the system, and one in which represent the transition between the two other states. The modes are states of adaptational capacity, which in other words means that when stress increases (from external factors) a system have "additional" resources that can be used in order to maintain a stable performance up until a certain degree. Hancock and Warm's (1989) model shares similarities with other resource-based cognitive theories such as Wickens (1984, 1987) multiple resource theory (MRT). In short, Wickens MRT model suggests that a human does not have a single information processing unit, but there are rather several "pools" of resources that can be used simultaneously. When performing several tasks at once, depending on the nature of the tasks, they may or may not interfere with each other; if for example two verbal tasks are performed simultaneously, they are likely to interfere with each other and performance declines. In practice this essentially means that task workload can be measured using a secondary task over a primary task. By comparing the result of the performance on a primary task performance with the performance on primary task *with* a secondary task it is possible to assess the degree which the secondary task interferes (or not) with the primary task or the workload capacity of the operator (Wickens, 1979).

The core of Hancock and Warms (1989) model is concept of adaptability in both physiological of psychological terms. Hockey (1997) suggested in his article a cognitive-energetical framework, in which he shares the view of Hancock and Warm (1989) that a human performance model must include the construct of mental resources. However, Hockey's (1997) framework includes the energetical perspective as well. The idea is that energetical resources can be directed through mental *effort*. Maintaining performance stability during demanding conditions is an active process controlled by an operator; this in turn requires the operator to manage his cognitive resources through the mobilization of mental effort (Hockey, 1997). Hockey (1997) describes this regulatory process as two-sided loop, where one loop is automatic, whereas the other one is effort-based. In cases were workload increases high enough the lower level automatic loop fails to function and the operator must consciously redistribute the mental resources. This process is goal-based, which means that the operator can choose to either 1) increase effort to maintain the target state performance, which means increased energetical costs (i.e. increased physiological work; e.g.

higher heart rate), or 2) modify the target state, which essentially means to lower the performance and staying at the same energetical level (Hockey, 1997).

With the above concepts in mind, it is possible to see that although individual differences in the models and theories exists, the commonalities are there; Lazarus and Folkmans (1984) transactional theory states that stress is not a property of the environment but rather the interplay between the individual and the environment and how the individual appraises and copes with the environment. Matthews (2001) expanded the transactional theory by suggesting that stress can be described by using different levels of explanation. The DSSQ is one assessment method for examining the subjective nature of stress (Matthews, Campbell, Falconer, & Gilliland, 2002; Matthews et al., 1999). Hancock and Warm's (1989) and Hockey's (1997) models both emphasize that stress and workload are controlled by regulatory processes where pooled resources can be managed by an operator accordingly to the demands of the task at hand and the environment, at the cost of increased mental and physiological demands. Methodologically speaking, stress can then be measured using physiological measures, such as heart rate and heart rate variability to assess the energetical aspect of stress, as well as using performance measures with or without secondary tasks, and subjective reports of mental workload (Hancock & Warm, 1989; Hockey, 1997; Nibbeling, Oudejans, & Daanen, 2012; Wickens, 1979).

3 Method

In this chapter the method of the study will be presented. The chapter will contain sections about the study design, participants and ethics, material, the secondary task administered, procedure of the experiment and finally the analytical methods.

3.1 Study design

This study used a mixed experimental design with group (layperson, fire rescue services, and emergency medical services) as the between-subjects variable. Each group was exposed to the same treatments. Participants repeatedly answered questionnaires and performed tourniquet application and CPR, hence those are within-subjects variables.

3.2 Participants and Ethics

For this study 55 participants (9 women, 46 men), aged between 18-63 ($M = 34.02$, $SD = 11.26$), were recruited through e-mail, social media, word-of-mouth and through various contacts at the Centre for Disaster Medicine and Traumatology in Linköping, Sweden. During the recruitment participants were informed that the experiment was within the area of disaster medicine and hemorrhage control under calm and stressful conditions. Participants were also informed that they would be subject for an obstacle course and paintball fire. Participants were divided into three groups, laypersons, fire rescue workers and emergency medical service (EMS) workers, according to prior health care experience and knowledge, as well as current profession. Inclusion criteria for participation was speaking Swedish and a minimum age of 18.

The study was approved by the Regional Ethical Board in Linköping at 2018-08-15, reference number: 2018/305-31. Every participant gave a written consent before the experiment.

3.3 Material

In this section all the material used in the study will be presented. The materials includes surveys, educational program, tourniquet and tourniquet assessment template, CPR equipment, physiological measurement equipment, and paintball equipment.

3.3.1 Surveys.

In total four surveys were issued to the participants throughout the experiment: DSSQ (three times), NASA-TLX (four times), a pre survey and a post survey.

3.3.1.1 DSSQ.

The DSSQ consists of four parts each divided into 29,15, 30 and 16 questions. The survey was filled out three times during the experiment: pre-experiment, after the calm scenario, and after the stressful scenario. For this study a Swedish translated version of the DSSQ was used.

3.3.1.2 NASA-TLX.

The NASA-Task Load Index (NASA-TLX) is a subjective mental workload rating scale that have been extensively used in mental workload research (Hart & Staveland, 1988, see Cain, 2007 for a review). The NASA-TLX consists of six component scales, mental demand, physical demand, temporal demand, effort, performance and frustration. The original NASA-TLX weights the scales individually, and then the participants are asked to compare them pairwise according to how important they perceive each subscale, so that they reflect the overall contribution to the overall mental workload. In this study, the Raw unweighted version of the NASA-TLX was used, which is simpler to apply compared to the original version since the subscales are not compared pairwise to each other. The Raw version of NASA-TLX have in previous studies shown to be either more sensitive, less sensitive and equally sensitive compared to the original NASA-TLX (Hart, 2006), and as such the Raw version was used (which will be denoted as NASA-TLX)

The NASA-TLX was filled out with pen and paper. Each scale is presented on a straight line going from 0 to 100, and the participant marks their own estimate on the line. For this study, a Swedish translated version of the NASA-TLX was used.

3.3.1.3 Pre survey.

A demographic pre-test questionnaire was issued before the experiment with questions regarding age, sex, education level, experience from emergency medical services, fire rescue services, military or the police, previous bleeding control education, physical training and paintball experience. The questionnaire also included four knowledge-based questions about hemorrhage control, and three Likert-type scale questions about attitude (scale 1-5, 1 = Completely against, 5 = Completely for), confidence of tourniquet usage if direct pressure is

ineffective or unpractical during calm and stressful settings (scale 1-5, 1 = Very insecure, 5 = Very secure), and confidence in CPR during calm and stressful settings (scale 1-5, 1 = Very insecure, 5 = Very secure).

3.3.1.4 *Post survey.*

A post-test questionnaire was issued after the experiment with the same knowledge-based questions from the pre-test questionnaire, the same three Likert-type scale questions about attitude, and confidence and willingness of tourniquet usage if direct pressure is ineffective or unpractical.

3.3.2 Educational program

For the introductory educational program, a 7-minute long video about pre-hospital hemorrhage control was shown to the participants. The video included the following: common facts about hemorrhage control and the effectiveness of pre-hospital hemorrhage control (in order to motivate the learner), the standard procedure to follow when encountering a victim with a catastrophic bleeding, facts about blood flow and blood volume from a catastrophic bleeding, practical demonstration of tourniquet application, and common mistakes when applying a tourniquet. Participants performed three practical tourniquet applications: on his/her own leg, on another participants leg, and on his/her own arm. An instructor demonstrated this while the participants applied the tourniquets. The instructor followed a pre-written manuscript on how to teach the tourniquet application. The instructor briefly demonstrated live how to perform CPR on a mannikin, mentioning three aspects of CPR: the depth, the release, and the pace of the compressions. Participants did not practically try this on their own. The video and the training exercises, along with the instructor manuscript, was largely based on the pedagogical guidelines suggested by Goolsby, Jacobs, et al. (2018), educational material from the STB initiative, along with material previously used in research at the Centre for Disaster Medicine and Traumatology in Linköping.

3.3.3 Tourniquet

For this study the Combat Application Tourniquet generation 7 (CAT-7) was used (see Figure 1 below). The CAT-7 is the standardized tourniquet used in the Swedish Armed Forces and it is commonly used by EMS personnel as well as law enforcement personnel in Sweden. It is also one of three recommended tourniquets by the US Tactical Combat Casualty Care (Butler, 2010). The CAT-7 consist of a Velcro constricting band which is applied on a limb by

inserting the strap through a buckle and attaching it to itself, the tourniquet is then tightened using a plastic windlass which is then attached into a plastic clip. Leftover strap is also secured in the clip. The windlass and the leftover strap are secured once more using a small Velcro strap attached over the clip. Time for application is then noted on the small Velcro strap (Lowndes et al., 2017).
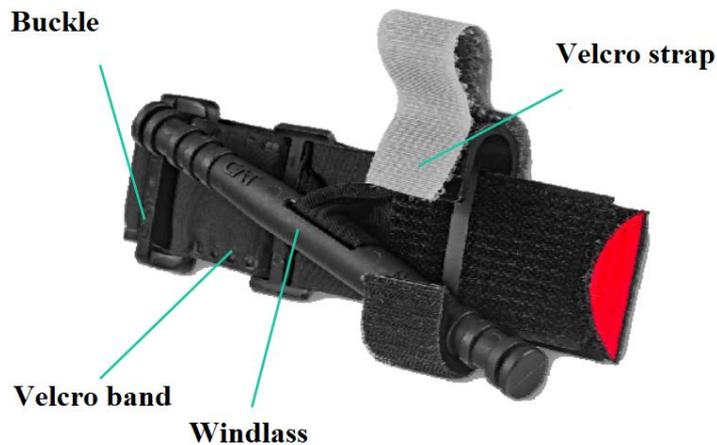
Figure 1. Labeled picture of a CAT-7.

3.3.4 Tourniquet assessment and manikin

For the calm scenario tourniquet application was performed on a 15kg SRP rescue manikin. For the stressful scenario, tourniquet application was performed on an 85-90kg SRP rescue manikin. Catastrophic bleeding was simulated by a red tape marking on the right leg of both manikins. The tourniquet was placed on the floor beside the manikin.

Tourniquet application performance was measured using a slightly revised assessment template based on Combat Medic Advanced Skills Training (CMAST), which have been used in previous studies (Lowndes et al., 2017). The assessment template included the following steps: tourniquet placement 5 cm approximal to the wound (yes/no), strap tightness (yes/no), windlass tightness (yes/no), windlass secured in clip (yes/no), extra strap secured in clip (yes/no), time strap secured over clip (yes/no), time notation on time strap (yes/no), tourniquet safe for transport (yes/no). The instructor graded the application and gave each step either 0 or 1 points, for maximum score of 8 points in total. The instructor also noted time to bleeding control (seconds) and the total time for application (seconds). During the experiment the participant were informed to start the application whenever they wanted and were given no instructions about time constraints. Time was measured from the moment the participant

grabbed the tourniquet until the participant reported "Done" to the instructor. For the tourniquet assessment template, see the Appendix.

3.3.5   CPR measurement and manikin.

Since CPR is a wide-known concept in the Swedish society, and it is very likely, that if not being taught CPR, at least the concept is known by every participant. Thus, it is expected that participants will be able to perform this task relatively well. Because of that, CPR will serve as a baseline measurement when comparing CPR and tourniquet application with the results from the DSSQ, NASA-TLX, the physiological measurements, and the secondary task.

CPR was performed on the simulation manikin: Laerdal Little Anne QCPR. The performance was recorded using the QCPR instructor app (Laerdal Medical AS, version 3.4.11), which measured: the average compression rate, depth (%) and the degree of release (%) between the compressions. Compressions was continuously performed for 90 seconds by the participant until the instructor ordered to stop. The secondary task was continuously performed simultaneously. In order to avoid interference with the secondary task, compressions only, without mouth-to-mouth ventilations, were chosen. This however is not necessarily negative since previous studies have shown that laypersons might hesitate to perform CPR due to fear of contracting diseases during the mouth-to-mouth ventilations or lack of confidence in how to perform the ventilations (Jelinek et al., 2001; Pehli van, Mercan, Çi Nar, Elmali, & Soyöz, 2019; Shibata, Taniguchi, Yoshida, & Yamamoto, 2000). Additional studies have shown that hand-only CPR can be just as good as CPR with mouth-to-mouth ventilations, in terms of survival outcomes, and thereby recommends hands-only CPR (Japanese Circulation Society Resuscitation Science Study Group, 2013; Rea et al., 2010; Svensson et al., 2010).

3.3.6   Heart rate and Heart rate variability

Hockey's (1997) cognitive-energetical framework explains how stable performance levels can be maintained during covert changes in the body's physiological states. Heart rate (HR) and heart rate variability (HRV) have been used as measures of stress because stress is associated with activity in the sympathetic (SNS) and parasympathetic nervous system (PNS) (Schubert et al., 2009a), as well as being associated with performance and subjective reports of mental states (Fairclough & Venables, 2006). Whereas heart rate might be more of a measure of overall task demand (Wilson, 2002), and measures the heart activity on the time

domain, HRV measures the heart's beat-to-beat interval (IBI), or R-R interval, on a frequency domain and pick up on more subtle differences in the heart activity (Schubert et al., 2009a). To analyze HRV power spectral analysis methods are used. The Low Frequency (LF) band (0.04-.15 Hz), reflects activity in the SNS and, in some portion the PNS, (H.-G. Kim, Cheon, Bai, Lee, & Koo, 2018) and has been showed to be sensitive to stress related concepts such as workload (Aasman, Mulder, & Mulder, 1987). In general, increased workload is indicated by a decrease in the LF band (for a review, see Boucsein & Backs, 2000), but activity in the LF band can be sensitive to different types of mental tasks. Visnovcova et al. (2014) for example, found that during a Stroop test, LF band activity decreased, whereas it increased during a mental arithmetic task. The High Frequency (HF) band (0.14-0.4 Hz), on the other hand, reflects activity in the PNS which typically decreases during acute stressful events (Pagani et al., 1997). The LF/HF ratio has been used to estimate the ratio between SNS and PSN activity (Shaffer, McCraty, & Zerr, 2014) and in some studies the LF/HF ratio seems to increase during stressful periods of the day when measured over a 24-hour period (Sloan et al., 1994). Measuring HR and HRV with commercially available heart rate monitors is a relatively non-intrusive method and is suitable for HR and HRV recordings when the participant is doing physical activity.

Measurements included in this study was: average HR (beats per minute), LF Power (ms^2), and the LF/HF ratio. Both HR and HRV data were recorded using a Polar H10 pulse recorder which was strapped around the participants' chest. The data was captured using the Elite HRV app (Perrotta, Jeklin, Hives, Meanwell, & Warburton, 2017), with both one Android and one iOS device, and was analyzed with the Kubios Standard (version 3.1.0.1) software (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014). The R-R data was extracted using an autoregressive power spectral density model and the "Very low" artifact autocorrection option was used. Time for the measurement during the calm scenario was from the moment the participants entered the classroom and ended after 330 seconds (the approximate time it took for the participant to hear the instructions, perform CPR, fill out two NASA-TLX and move between the stations), plus the individual time it took for the participant to completely apply the tourniquet. During the stressful scenario, time was measured from the moment the participants entered the training hall and ended after 500 seconds (approximated time between all the participants to complete the entire stressful scenario).

3.3.7 Paintball equipment

An Angel A1 Fly paintball marker was used during the stressful scenario to fire paintball shots at the participants. Powered by compressed air the muzzle velocity was set to 91 m/s. Ammunition was of reball type cal. 68. Both the instructor and the participants were wearing a mandatory eye- and face protection mask and the participant were also wearing a mandatory suspensor. Arm- and knee pads were also free to use for the participant. The participant was wearing the face mask and suspensor during both the calm and stressful scenario.

3.4 Secondary Task

In order to examine whether the CPR and tourniquet application differed from each other in terms of mental capacity and stress, a secondary task was added to both the CPR and tourniquet application station. The type of secondary task was chosen to not cognitively interfere with the two primary tasks (CPR and tourniquet application), i.e. the same cognitive resources involved when performing the primary task should not be involved in the performance of the secondary task, otherwise the secondary task could be too intrusive Wickens (1984).

The secondary task used in this study was a mental arithmetic task similar to the one used by Nibbeling et al. (2012). One three-digit number and one single digit number was written on a piece of paper above the CPR and tourniquet manikins. The task was to verbally subtract the three-digit number with the single digit number and obtain a difference. The difference was then subtracted once again with the same single-digit number. This procedure was then continuously repeated during the primary task (CPR or tourniquet application). Four different number pairs (one three-digit, and one single digit) were placed at each station and were randomized between the participants and the stations. Measures collected for the secondary task was reaction time, the total number of correctly verbally reported differences, and percentage (%) of correctly verbally reported differences. The secondary task was recorded using two GoPro HERO 5 mounted at each station for later analysis.

3.5 Procedure

This section presents the study procedure. For information about the surveys and materials, see the material section above. The experiment was conducted one participant at a time, meaning that the only person in the room was the participant and the instructor, except

for in pre-experiment setting were several participants could fill out the questionnaires at the same time. The procedure was the same for all participants (see Figure 1 below for a flow chart of the procedure), and was similar to the procedure used in the study by Schreckengaust et al. (2014). The calm scenario was also conducted before the stressful scenario in order to prevent the expected increased heart rate and heart rate variability activity form the stressful scenario to influence the measurements on the calm scenario (i.e. heart rate activity would not return to normal activity after the stressful scenario fast enough).

Pre-experiment setting	**Calm setting**	**Stressful setting**	**Post-experiment setting**
• Demograhphic survey • Post survey • DSSQ	• NASA-TLX x 2 • DSSQ	• NASA-TLX x 2 • DSSQ	• Post-survey • DSSQ
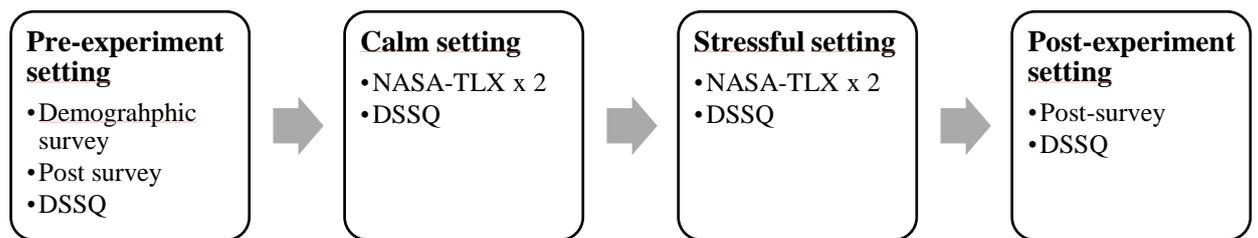
Figure 2. Procedure for the experiment with appurtenant surveys.

3.5.1 Calm and stressful settings layout.

The calm setting was divided into two stations in a classroom. Each station was approximately two meters from each other and had two plywood sheets (240 x 120 cm) placed onto a L-shaped configuration were the Laerdal Little Anne QCPR manikin was placed behind one of the configurations and the tourniquet manikin placed behind the other configuration. Two GoPro HERO 5 cameras was mounted on the plywood sheets, approximately 50 and 120 cm above the ground, at each station in order to record the performance for evaluation later on.

The stressful setting consisted of a short obstacle course (see more under the stressful setting section) in a training hall. Two plywood sheets acted as covers approximately 6 meters from each other. The stressful setting also had two stations placed in the same way as the calm setting approximately two meters behind the two plywood covers, with four meters in between the stations. The instructor firing the paintball marker was placed approximately 10 meters from the wooden covers in the middle of the training hall. See Figure 2 for a sketch of the stressful setting.
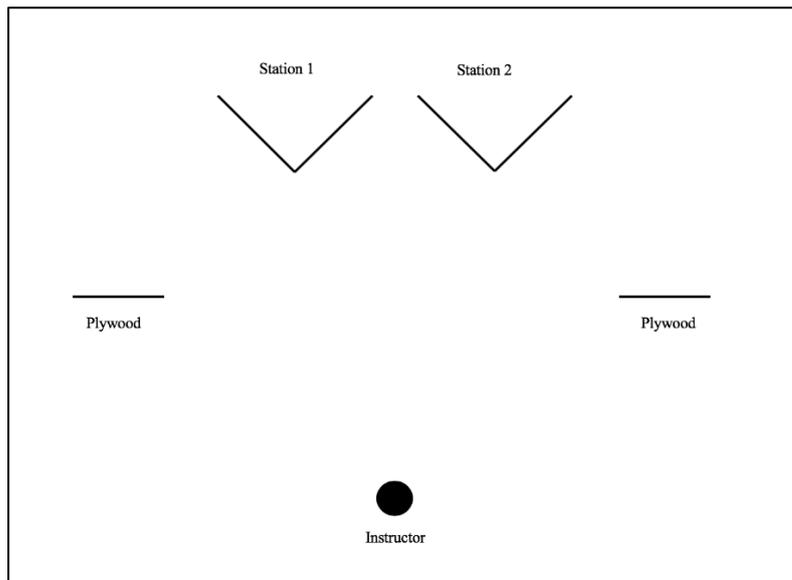
Figure 3. Sketch of the stressful setting.

3.5.2   Pre-experiment setting.

The study started out in a classroom were participants began by reading an information sheet about the study and its purpose and then signing a consent sheet about their participation in the study. Participants were also informed that they could end their participation at any time during the experiment without any reason as to why. They then filled out the pre-test demographic survey and a pre-test DSSQ questionnaire. An instructor then explained the study procedure: they were informed that their ability to perform tourniquet application and CPR during calm and stressful settings while being loaded with a secondary task were going to be tested throughout the experiment.

 After that participants watched a 7-minute long educational video about hemorrhage control followed by three practical tourniquet applications using a CAT-7 tourniquet. This training session was led by the instructor. The instructor then gave a demonstration on how to perform CPR on a Laerdal Little Anne QCPR manikin which covered basic anatomical features, compression frequency and the importance of the depth of the compressions and the release between the compressions. Before the calm scenario participants were led to a dressing room where they put on the paintball protection gear and the pulse recorder.

3.5.3   Calm setting.

The participant was then led into an adjacent classroom for the calm test scenario where an instructor explained the procedure. The participant started with either tourniquet

application or CPR (alternating between the participants). The number with the secondary task were placed on a piece of paper above the manikin. After the tourniquet application or CPR, the participant directly filled out a NASA-TLX questionnaire, and then moved on to the next station, after completion of the second station another NASA-TLX questionnaire were filled out. A DSSQ questionnaire were then filled out after the completion of both stations.

3.5.4 Stressful setting.

Following the calm scenario, the participant was led into an adjacent training hall for the stressful scenario where the instructor once again explained the procedure. The initial starting position for the participant was laying face down on the floor behind the wooden cover. The participant was instructed to run to the second cover, when the instructor gave the command "run", and lay down face down behind the second cover. During the running phase the participant was subject to paintball fire, and when the participants was laying down behind the wooden cover, paintball bullets were fired at the cover by the instructor. This procedure was repeated eight times, four times back and forth, until the instructor commanded either "Station one", or "Station two" (alternating between the participants as during the calm scenario). The participant then ran to either station and performed tourniquet or CPR while being loaded with the secondary task. No paintball bullets were fired during the time the participant was at either station. After the completion of the tourniquet application or CPR, a NASA-TLX questionnaire was directly filled out by the participant. The participant was then instructed to lay face down on the floor behind the first cover once again, and the running procedure, and the paintball firing, was repeated once again followed by the second station and a NASA-TLX questionnaire.

3.5.5 Post-experiment setting.

After the stressful scenario the participant was led to an adjacent classroom where a post-test DSSQ questionnaire and a post-test questionnaire were filled out. The protection gear could be removed at this point. When all the participants had completed all scenarios, the experiment ended with a short round-up session where participants were given feedback at a group level about their performance, and questions regarding the experiment were answered.

3.6 Analytical Methods

All statistical analysis was conducted using IBM SPSS Statistics (Version 24). Outliers was identified and removed using the box plot feature in SPSS. Each variable was examined

separately and values that were 3 times the interquartile range was removed from the analysis. In order to test for sphericity for the split-plot ANOVA:s Mauchly's test of sphericity (Mauchly's W) was used. In cases were Mauchly's test was significant ($p < .05$) the degrees of freedom was corrected using either Greenhouse-Geisser ($\varepsilon < .75$) or Huynh-Feldt ($\varepsilon > .75$) correction (Girden, 1992). For all follow up multiple comparison tests Šidák corrections was used.

4 Results

In this chapter results from the statistical tests will be presented. The results are divided into the following sections: descriptive statistics, tourniquet assessment template, self-assessed ability, tourniquet and CPR performance, DSSQ, NASA-TLX, secondary task, and HR and HRV.

4.1 Descriptive Statistics

Demographic data was collected from the participants using the pre-survey. The descriptive statistics from the pre survey are found in Table 1 below.

Table 1.

Descriptive statistics from the demographic pre survey.

	Laypersons	Fire Rescue	EMS
Nr. of participants	24	20	11
Age	26	39	42
Women	6	1	2
Men	18	19	99
Fire rescue	0	12.85	3.33
EMS	0	0	13.3
Health care	5.67	24	10.85

Note. Age represents the mean age for each group. The three rows fire rescue, EMS and Health care, represents years of experience from fire rescue service, emergency medical service and health care service.

4.2 Tourniquet Assessment Template

Table 2 below shows the results, for all three groups, from the tourniquet application which was scored using the tourniquet assessment template. See the Appendix for the exact template used.

Table 2.

Tourniquet assessment across groups and conditions.

Step	Laypersons		Rescue service		EMS	
	Calm	Stressful	Calm	Stressful	Calm	Stressful
Tourniquet placement	23 (95.8)	24 (100)	20 (100)	20 (100)	11 (100)	11 (100)
Strap tightness	23 (95.8)	22 (91.7)	20 (100)	20 (100)	11 (100)	11 (100)
Windlass tightness	21 (87.5)	24 (100)	20 (100)	20 (100)	11 (100)	11 (100)
Secured windlass	23 (95.8)	24 (100)	20 (100)	20 (100)	11 (100)	11 (100)
Excess strap secured	15 (62.5)	20 (83.3)	16 (80)	17 (85)	6 (54.5)	8 (72.7)
Time strap secured	22 (91.7)	22 (91.7)	20 (100)	20 (100)	11 (100)	11 (100)
Time noted	14 (58.3)	13 (54.2)	10 (50)	16 (80)	6 (54.5)	8 (72.7)
Safe for transport	21 (87.5)	21 (87.5)	20 (100)	18 (90)	11 (100)	11 (100)
Performance	6.7	7.1	7.3	7.6	7.1	7.5
Time to (s) bleeding control	66	69	49	46	43	41
Total time (s)	83	82	66	57	54	54

Note. The values represent the n number of participants who correctly followed each step, percentage of participants, per group, is within parentheses. Performance is a number from 0 to 8 indicating the mean number of correctly performed steps.

4.3 Self-Assessed Ability

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine self-assessed tourniquet application ability under calm circumstances. The results showed a significant main effect of condition, $F(1, 51) = 24.53$, $p < .001$, $\eta p^2 = .325$, as well as a significant main effect of group $F(2, 51) = 16.224$, $p < .001$, $\eta p^2 = .381$. A significant interaction effect between group and pre- and post-experiment assessment $F(2, 51) = 8.00$, $p = .001$, $\eta p^2 = .239$ was also found.

In order to examine how self-assessed tourniquet application ability differed between the groups, two one-way ANOVA tests were conducted. The first one-way ANOVA compared the effects of group on the pre-experiment self-assessed tourniquet application ability during calm circumstances. The results showed a significant effect $F(2, 52) = 15.28$, $p < .001$, $\eta p^2 = .370$. A post hoc test showed that laypersons assessed their tourniquet application ability during calm circumstances significantly lower ($M = 2.71$ $SD = 1.27$) than fire rescue workers ($M = 4.20$, $SD = 1.11$), $p < .001$ (95% CI [0.68,2.31]) and EMS workers ($M = 4.64$, $SD = .67$), $p < .001$ (95% CI [0.95,2.91]) before the experiment.

The second one-way ANOVA compared the effect of group on post-experiment self-assessed tourniquet application ability during calm circumstances. The results showed a significant effect $F(2, 52) = 3.96$, $p = .025$, $\eta p^2 = .134$. A post hoc test showed that laypersons ($M = 4.33$, $SD = .87$) significantly assessed their tourniquet application during calm circumstances ability lower than fire rescue workers ($M = 4.84$, $SD = .37$) with an average of .51 standard deviations $p = .041$ (95% CI [0.03,1.00]) after the experiment.

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine self-assessed tourniquet application ability under stressful circumstances. The results showed a significant main effect between pre- and post-experiment assessment, $F(1, 51) = 57.78$, $p < .001$, $\eta p^2 = .531$, and a significant main effect of group $F(2, 51) = 12.954$, $\eta p^2 = .337$. A significant interaction effect between pre- and post-experiment assessment and group $F(2, 51) = 5.77$, $p = .005$, $\eta p^2 = .185$, was also found.

In order to examine how self-assessed tourniquet application ability during stressful circumstances differed between the groups, two one-way ANOVA tests were conducted. The first one-way ANOVA compared the effects of group on the *pre*-experiment self-assessed tourniquet application ability. The results showed a significant effect $F(2, 52) = 16.94$, $p < .001$, $\eta p^2 = .394$. A post hoc test showed that laypersons ($M = 1.95$, $SD = .95$) significantly assessed their tourniquet application ability lower than fire rescue workers ($M = 3.1$, $SD = .85$) with an average of 1.14, $p < .001$ (95% CI [0.48, 1.81]) when asked before the experiment. Laypersons did also significantly assess their tourniquet application ability lower than EMS workers ($M = 3.73$, $SD = 1.15$) by an average of 1.77, $p < .001$ (95% CI [0.97, 2.57]) before the experiment. The second one-way ANOVA compared the effect of group on *post*-experiment self-assessed tourniquet application ability during stressful circumstances. The results showed a non-significant effect, $F(2, 51) = 2.37$, $p = .104$, $\eta p^2 = .085$.

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine self-assessed CPR ability under calm circumstances. The results showed a significant main effect of group $F(2, 51) = 22.381$, $p < .001$, $\eta p^2 = .467$, such that laypersons assessed their CPR ability significantly lower ($M = 3.90$, $SD = 1.95$) than fire rescue workers ($M = 4.84$, $SD = .53$), $p < .001$ (95% CI [-1.36,-0.53]) and EMS workers ($M = 5.00$, $SD = 0.00$), $p < .001$ (95% CI [-1.60,-0.61]). No significant main effect of condition or interaction effect was found.

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine self-assessed CPR ability under stressful circumstances before and after the experiment. The results showed a significant main effect between pre- and post-experiment assessment $F(1, 51) = 13.36$, $p = .001$, $\eta p^2 = .208$. A follow up pairwise comparison showed that across all groups, pre-experiment assessment scores were lower ($M = 3.44$, $SD = 1.08$), $p = .001$, than post-experiment assessment scores ($M = 3.94$, $SD = 0.94$). A significant main effect on group $F(2, 51) = 20.691$, $\eta p^2 = .448$ was also found, such that laypersons ($M = 3.04$, $SD = 0.97$) assessed their CPR ability lower than fire rescue workers ($M = 4.05$, $SD = 1.00$), $p < .001$ (95% CI [-1.53,-0.49]), and EMS workers ($M = 4.5$, $SD = 0.71$), $p < .001$ (95% CI [-2.10, -0.84]). No significant interaction effect was detected.

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine opinion towards tourniquet usage if direct pressure is ineffective or unpractical, before and after the experiment. A significant main effect of condition was detected $F(1, 50) = 7.68$, $p = .008$, $\eta p^2 = .133$, such that across all groups, participants became more positive towards tourniquet usage from before experiment ($M = 4.45$, $SD = .80$) to after the experiment ($M = 4.80$, $SD = .66$), $p = .008$. A significant main effect on group was also found $F(2, 50) = 4.80$, $\eta p^2 = .161$, such that laypersons tourniquet usage opinion ($M = 4.35$, $SD = 0.95$) was lower than EMS workers' opinion ($M = 4.95$, $SD = 0.80$), $p = .018$ (95% CI [-0.83, 0.05]). No significant interaction effect was detected.

A 3 (group) x 2 (pre, post) ANOVA was conducted to examine the results of the knowledge-based questions that was asked before and after the experiment. A significant main effect of condition was found $F(1, 48) = 30.00$, $p < .001$, $\eta p^2 = .384$, such that for all groups, knowledge based scored increased from before the experiment ($M = 2.71$, $SD = .70$) to after the experiment ($M = 3.63$, $SD = .69$). No other effects were found.

4.4 Tourniquet and CPR Performance

A 3 (group) x 2 (calm, stress) ANOVA was conducted to examine the time to bleeding control for the tourniquet application. The results showed no significant main effect of condition $F(1, 50) = .07$, $p = .80$, $\eta p^2 = .001$, but a significant main effect of group was found $F(2,50) = 12.296$, $p < .001$, $\eta p^2 = .330$, such that laypersons ($M = 68.41$, $SD = 30.14$) were significantly slower than both fire rescue workers ($M = 47.42$, $SD = 10.48$), $p = .001$ (95% CI [8.10,33.89]) and EMS workers ($M = 42.36$, $SD = 15.31$), $p < .001$ (95% CI [10.80, 41.30]). No significant interaction effect $F(2, 50) = .21$, $p = .81$, $\eta p^2 = .008$ was found.

A 3 (group) x 2 (calm, stress) ANOVA was conducted in order to examine the total time for tourniquet application. The results showed no significant main effect of condition $F(1, 49) = 1.08$, $p = .303$, $\eta p^2 = .022$, but a significant main effect of group was found $F(2, 49) = 11.121$, $p < .001$, $\eta p^2 = .312$, such that such that laypersons ($M = 83.33$, $SD = 41.13$) were significantly slower than both fire rescue workers ($M = 61.58$, $SD = 21.43$), $p = .002$ (95% CI [7.00, 36.48]) and EMS workers ($M = 54.54$, $SD = 16.93$), $p < .001$ (95% CI [11.61, 45.95]). No significant interaction effect $F(2, 49) = .50$, $p = .61$, $\eta p^2 = .020$.

A 3 (group) x 2 (calm, stress) ANOVA was conducted in order to examine the performance score of the tourniquet application. A significant main effect on condition was found $F(1, 52) = 4.42$, $p = .040$, $\eta p^2 = .079$, such that across all groups, tourniquet performance scores were higher in the stressful scenario ($M = 7.32$, $SD = .96$) compared to the calm scenario ($M = 7.02$, $SD = .93$), by an average of .316 standard deviations ($p = .040$). No other significant effects were found.

A 3 (group) x 2 (calm, stress) ANOVA was conducted in order to examine the percentage of correct CPR compressions with enough depth between groups. The results showed no significant main effect of condition $F(1, 40) = 1.54$, $p = .222$, $\eta p^2 = .037$ and no significant main effect of group $F(2, 40) = .447$, $p = .642$, $\eta p^2 = .022$. No significant interaction effect $F(2, 40) = .93$, $p = .405$, $\eta p^2 = .044$ was detected.

A 3 (group) x 2 (calm, stress) ANOVA was conducted in order to examine CPR compression release between the groups. The results showed a significant main effect of condition $F(1, 44) = 5.29$, $p = .026$, $\eta p^2 = .107$, such that across all groups CPR compression release was higher during the calm scenario ($M = 57.06$, $SD = 39.79$) than during the stressful scenario ($M = 39.00$, $SD = 39.54$), $p = .026$. No other significant interactions were found.

A 3 (group) x 2 (calm, stress) ANOVA was conducted in order to examine CPR compression frequency. No significant main effect of condition was detected $F(1, 43) = 1.65$, $p = .206$, $\eta p^2 = .037$, and no significant main effect of group was detected $F(2, 43) = 1.202$, $p = .311$, $\eta p^2 = .053$. No significant interaction effect was detected $F(2, 43) = .10$, $p = .905$.

4.5   DSSQ

A 3 (group) x 3 (condition) split-plot ANOVA was conducted on Task engagement. A significant main effect of condition was found, $F(1.81, 94.13) = 5.50$, $p = .007$, $\eta p^2 = .096$, such that across all groups, task engagement increased from the pre-experiment ($M = 0.02$, $SD = 0.75$) to the stressful scenario ($M = 0.36$, $SD = 0.64$), $p = .021$ (95% CI [-0.60, -0.39]). No significant main effect on group or interaction effect was found.

A 3 (group) x 3 (condition) split-plot ANOVA was conducted on Distress. A significant main effect of condition was found, $F(2, 102) = 20.815$, $p < .001$, $\eta p^2 = .290$, such that for all groups, distress increased from the pre-experiment scenario ($M = 0.03$, $SD = 0.77$) to the calm scenario ($M = 0.77$, $SD = 1.01$), $p < .001$ (95% CI [-1.00, -0.42]) and the stressful scenario ($M = 0.67$, $SD = 0.96$), $p < .001$ (95% CI [-0.93, -0.31]). A significant main effect of group was also found $F(2, 51) = 9.494$, $p < .001$, $\eta p^2 = .271$, such that layperson reported higher distress ($M = 0.94$, $SD = 1.59$) than fire rescue workers ($M = 0.15$, $SD = 1.22$), $p = .001$ (95% CI [0.28, 1.30]) and EMS workers ($M = 0.19$, $SD = 1.45$), $p = .005$ (95% CI [0.22, 1.48]). No significant interaction effect was found.

A 3 (group) x 3 (condition) split-plot ANOVA was conducted on Worry. A significant main effect of condition was found, $F(1.467, 96) = 59.74$, $p < .001$, $\eta p^2 = .554$, such that for all groups worry was higher in the pre-experiment scenario ($M = 0.01$, $SD = 0.68$) compared to the calm scenario ($M = -0.77$, $SD = 0.63$), $p < .001$ (95% CI [0.52, 1.01]) and the stressful scenario ($M = -0.88$, $SD = 0.63$) $p < .001$ (95% CI [0.63, 1.14]). A significant main effect of group was also found $F(2, 48) = 3.847$, $p = .028$, $\eta p^2 = .138$, such that laypersons reported a higher worry ($M = -.31$, $SD = 1.11$) than fire rescue workers ($M = -0.69$, $SD = 1.24$), $p = 0.34$ (95% CI [0.03, 0.84]). No significant interaction effect was found.

4.6   NASA-TLX

The NASA-TLX scores were analyzed using a series of 3 (group) x 2 (calm, stress) x 2 (tourniquet, CPR) split-plot ANOVAs on each of the six subscales, and on the total NASA-TLX score.

The ANOVA on mental demands showed a significant main effect of task $F(1, 52) = 5.38$, $p = .024$, $\eta p^2 = .094$. A significant two-way interaction effect between task and group was also found $F(2, 52) = 3.31$, $p = .044$, $\eta p^2 = .113$.

In order to follow up the interaction effect two paired t-test for each group was conducted, comparing the mean values between the task for each condition. For laypersons during the calm scenario there was no significant difference in mental demand between CPR ($M = 57.22$, $SD = 25.61$) and tourniquet application ($M = 59.24$, $SD = 21.93$), $t(23) = -.345$, p .733. For the stressful scenario a similar pattern was found. There was no significant difference in mental demand between CPR ($M = 61.25$, $SD = 20.00$) and tourniquet application ($M = 60.76$, $SD = 20.01$), $t(23) = 0.134$, $p = .894$.

For fire rescue workers during the calm scenario there was a significant difference in mental demand. Mental demand was higher during CPR ($M = 54.42$, $SD = 25.19$) compared to during tourniquet application ($M = 37.33$, $SD = 28.04$), $t(19) = 3.109$, $p = .006$. For the stressful scenario mental demand was once again higher during CPR ($M = 57.28$, $SD = 23.19$) compared to during tourniquet application ($M = 48.47$, $SD = 26.20$), $t(19) = 2.582$, $p = .018$.

For EMS workers during the calm scenario there was no significant difference in mental demand between CPR ($M = 54.14$, $SD = 28.04$) and tourniquet application ($M = 46.42$, $SD = 29.02$), $t(10) = 0.906$, $p = .386$. During the stressful scenario there was no significant difference in mental demand between CPR ($M = 55.30$, $SD = 21.15$) and tourniquet application ($M = 52.53$, $SD = 18.67$), $t(10) = 0.826$, $p = .428$.

The ANOVA on physical demand scores showed a significant main effect of condition $F(1, 48) = 199.815$, $p < .001$, $\eta p^2 = .806$, and significant main effect of task $F(1, 48) = 14.013$, $p < .001$, $\eta p^2 = .226$. A significant interaction effect between condition and task, $F(1, 48) = 40.006$, $p < .001$, $\eta p^2 = .455$ was also found. In order to follow up the interaction effect between task and condition a paired-samples t-test was conducted on CPR and tourniquet application during the calm and stressful scenario. There was a significant difference in physical demand between CPR ($M = 33.86$, $SD = 20.72$) and tourniquet application ($M = 16.01$, $SD = 20.16$) during the calm scenario, $t(50) = 6.40$, $p < .001$. But for the stressful scenario, there was no significant difference in physical demand between CPR ($M = 52.44$, $SD = 24.73$) and tourniquet application ($M = 65.15$, $SD = 23.06$), $t(54) = -.971$, $p = .336$.

The ANOVA on temporal demand scores showed a significant main effect of condition $F(1, 52) = 46.182$, $p < .001$, $\eta p^2 = .470$, such that regardless of group temporal demand was lower in the calm scenario ($M = 32.79$, $SD = 35.46$) compared to the stressful scenario ($M =$

51.86, $SD = 34.68$), $p < .001$ (95% CI [-26.04, -14.17]). No other significant effects were found.

The ANOVA on performance scores showed no significant main or interaction effects.

The ANOVA on effort scores showed a significant main effect of condition $F(1, 52) = 110.350$, $p < .001$, $\eta p^2 = .680$, and a significant main effect of task, $F(1, 52) = 5.875$), $p = .019$, $\eta p^2 = .102$. A significant main effect of group was also found $F(2, 52) = 5.223$, $p = .009$, $\eta p^2 = .167$, such that laypersons significantly reported a higher effort ($M = 64.54$, $SD = 38.65$) than fire rescue workers ($M = 48.51$, $SD = 44.10$), $p = .007$ (95% CI [3.75, 28.32]). A significant interaction effect between condition and task was also found $F(1, 52) = 5.420$, $p = .024$, $\eta p^2 = .094$.

In order to follow up the interaction effect between task and condition a paired-samples t-test was conducted on CPR and tourniquet application during the calm and stressful scenario. There was a significant difference in effort between CPR ($M = 48.74$, $SD = 22.32$) and tourniquet application ($M = 40.43$, $SD = 26.21$), t(54) = 2.678, $p = .01$ during the calm scenario. There was no significant difference in effort between CPR ($M = 70.41$, $SD = 19.76$) and tourniquet application ($M = 68.13$, $SD = 17.88$) during the stressful scenario, t(54) = 1.355, $p = .181$.

The ANOVA on frustration scores showed a significant main effect of condition $F(1, 52) = 9.928$, $p = .003$, $\eta p^2 = .160$, such that regardless of group frustration was lower in the calm scenario ($M = 36.03$, $SD = 35.31$) compared to the stressful scenario ($M = 45.56$, $SD = 32.46$), $p = .003$ (95% CI [-16.97, -3.77]). A significant main effect of group was also found $F(2,52) = 3.326$, $p = .044$, $\eta p^2 = .113$, however using Šidák adjustment for the estimated marginal means, no significant differences between the groups could be found. No significant interaction effect was found.

The ANOVA for total scores showed a significant main effect of condition, $F(1, 52) = 115.352$, $p < .001$, $\eta p^2 = .689$, and task, $F(1, 52) = 14.556$, $p < .001$, $\eta p^2 = .219$. A significant effect of group, $F(2, 52) = 5.526$, $p = .007$, $\eta p^2 = .175$, was also found such that laypersons had significantly higher total scores ($M = 54.34$, $SD = 32.88$) than fire rescue workers ($M = 40.64$, $SD = 34.97$), $p = .005$ (95% CI [3.47, 23.94]). A significant interaction effect between condition and task was found $F(1, 52) = 6.48$, $p = .014$, $\eta p^2 = .111$.

In order to follow up the interaction effect between task and condition a paired-samples t-test was conducted on CPR and tourniquet application during the calm and stressful

scenario. There was a significant difference in total score between CPR (M = 41.85, SD = 17.10) and tourniquet application (M = 34.28, SD = 18.95), t(54) = 3.528, p < .001 during the calm scenario. But there was no significant difference in total score between CPR (M = 58.44, SD = 16.89) and tourniquet application (M = 56.53, SD = 16.93) during the stressful scenario, t(54) = 1.504, p = .138.

4.7   Secondary Task

Secondary task scores were analyzed using a set of 3(group) x 2 (calm, stress) x 2 (tourniquet, CPR) split-plot ANOVAs to examine reaction time, numbers of errors, total correct answers and percentage of correct answers.

The ANOVA on reaction time showed a significant main effect of task F(1, 2) = 22.425, p < .001, ηp^2 = .436, such that regardless of group or condition reaction time was faster while performing CPR (M = 5.91, SD = 5.50) compared to when performing tourniquet application (M = 9.35, SD = 7.85), p < .001 (95% CI [-5.13, -2.04]). No other significant effects were found.

The ANOVA on total numbers of errors showed a significant main effect of condition F(1, 37) = 5.164, p = .029, such that regardless of group and primary task, the number of errors were lower in the calm scenario (M = 1.1, SD = 2.49) compared to the stressful scenario (M = 1.73, SD = 3.17), p = .029 (95% CI [-1.21, -0.07]). A significant main effect of task was found F(1, 37) = 8.785, p = .005, ηp^2 = .192, such that regardless of group and condition the number of errors were higher when performing the CPR (M = 1.95, SD = 3.64) compared to when performing tourniquet application (M = 0.88, SD = 1.75), p = .005 (95% CI [0.31, 1.65]). A significant main effect of group was also found F(2, 37) = 4.537, p = .017, ηp^2 = .197, such that regardless of condition and primary task, laypersons (M = 2.10, SD = 5.35) made more errors during the secondary task compared to fire rescue workers (M = 0.92, SD = 2.48), p = .025 (95% CI [0.13, 2.23]). No other significant main or interaction effects were found.

The ANOVA on total number of correct answers showed a significant main effect of task F(1, 36) = 58.826, p < .001, ηp^2 = .620, such that regardless of group and condition correctly reported numbers on the secondary task was higher when performing CPR (M = 15.82, SD = 14.85) compared to when performing tourniquet application (M = 6.05, SD = 5.60), p < .001 (95% CI [7.72, 13.27]).

The ANOVA on the percentage of correct answers showed a significant main effect of group $F(2, 32) = 4.557$, $p = .018$, $\eta p^2 = .222$, such that regardless of condition and task laypersons ($M = 0.81$, $SD = 0.49$) had a lower percentage of correct numbers on the secondary task compared to fire rescue workers ($M = 0.93$, $SD = 0.22$), $p = .018$ (95% CI [-0.22, -0.02]). No other significant effects were found.

4.8   HR and HRV

A 3 (Group) x 2 (condition) split-plot ANOVA was conducted in order to examine the average heart rate during the calm and stressful scenario between the groups. The results showed significant main effect of condition $F(1, 32) = 178.160$, $p < .001$, $\eta p^2 = .848$, such that across all groups the average heart rate increased from the calm scenario ($M = 97.14$, $SD = 17.29$) compared to the stressful scenario ($M = 134,56$ $SD = 15.11$), $p < .001$ (95% CI [-44.17, -32.47]). No other significant effects were found.

A 3 (Group) x 2 (condition) split-plot ANOVA was conducted in order to examine the Low Frequency power during the calm and stressful scenario between the groups. The results showed a significant main effect of condition $F(1, 29) = 17.46$, $p < .001$, $\eta p^2 = .376$, such that across all groups Low Frequency Power decreased from the calm scenario ($M = 963.55$, $SD = 662.18$) compared to the stressful scenario ($M = 469.87$, $SD = 508.35$), $p < .001$ (95% CI [281.93, 822.51]). A significant main effect of group was also found $F(2, 29) = 6.68$, $p = .004$, $\eta p^2 = .316$, such that laypersons had a higher LF Power ($M = 927.12$, $SD = 777.85$) than fire rescue workers ($M = 318.90$, $SD = 489.95$), $p = .003$ (95% CI [186.04, 1030.41]). No significant main effect was found.

A 3 (Group) x 2 (condition) split-plot ANOVA was conducted in order to examine the LF/HF ratio during the calm and stressful scenario between the groups. The results showed a significant main effect of condition $F(1, 31) = 5.263$, $p = .029$, $\eta p^2 = .145$, such that across all groups the LF/HF ratio decreased during the calm scenario ($M = 4.44$, $SD = 2.85$) compared to the stressful scenario ($M = 3.10$, $SD = 2.09$), $p = .029$ (95% CI [0.14, 2.43]).

5 Discussion

In this chapter the results of the study will be discussed in relation to the purpose and hypotheses of this study specified in the introduction. Thereafter, methodological aspects of the study will be discussed.

5.1 Result Discussion

The purpose of this study was to investigate how the performance of two first aid interventions, tourniquet application and CPR, is affected by stress in immediate (layperson) and first (professional) responders. From this purpose, four (null) hypotheses were formed and tested, each hypothesis (together with associated alternative hypothesis) will be discussed separately. Although, when referring to the "first hypothesis" for example, it refers to the null hypothesis $H_0 1$.

$H_0 1$: Tourniquet and CPR performance will be equal during the stressful scenario and the calm scenario across all groups.

$H_1 1$: Tourniquet and CPR performance will be lower during the stressful scenario compared to the calm scenario across all groups.

In the current literature, only one study has (explicitly) examined the effect of stress on tourniquet application. Schreckengaust et al. (2014) conducted a study where they examined the effects of stress on tourniquet application in a *military* population. Their hypothesis were that high tourniquet failure rates were due to the stressful nature of the battlefield which worsened the performance. Hence, they tested their subjects on tourniquet application during calm and stressful circumstances. Their results showed that their three tourniquet performance measurements: placement accuracy, elimination of pulse, and application time, all increased (or decreased in terms of time) between two calm scenarios, but then dropped during the stressful scenario. This was supposedly an effect of stress. In order to validate Schreckengaust et al.'s (2014) findings the current study aimed to replicate their study. Thus, the first hypothesis was formed. The results showed that there was no significant effect of condition on time to bleeding control and total time application time, although time increased for all groups, which is contrary to the findings of Schreckengaust et al. (2014). However, a significant effect of condition on the performance scores was found which indicated that across all groups, performance increased during the stressful scenario. This could possible indicate a training effect, participants did simply become better at tourniquet application, but

also that the stressful scenario was not in fact stressful at all or not stressful enough to affect the application times.

In order to examine if this explanation could be true, the CPR task was chosen to serve as a baseline measurement. If CPR performance for example declines during the stressful scenario, it would indicate that there was *something* in the scenario affecting the performance, stress being a reasonable guess. Three CPR performance variables were examined: compression depth, compression frequency and compression release. Compressions release was the only variable showing any effects, where the release rates (correct percentage) declined during the stressful scenario. Fried et al. (2011) examined the concept of leaning (incomplete recoil) and their study showed that contrary to the hypothesis that the CPR performer would be fatigued the longer they performed CPR, leaning decreased over time (to almost 0% after 180 seconds). Their study showed that this was true in instances were live feedback was provided, and it is reasonable to believe that this simply was an effect of fatigue in the stressful scenario (which also possible can be spotted in the physiological data, which will be returned to down below), but if the CPR time was prolonged the decline in release rate maybe would not be present.

$H_0$2: Laypersons tourniquet application and CPR performance will be equal to the performance of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.

$H_1$2: Laypersons tourniquet application and CPR performance will be lower than that of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.

As mentioned above, Schreckengaust et al.'s (2014) study was the only study that had examined the effects of stress on tourniquet application. For laypersons, no such study was found. Goolsby, Strauss-Riggs, et al. (2018) suggested that in a layperson population, stress would likely occur if a layperson were to be an immediate responder in a trauma scenario with a catastrophic bleeding present. As such, laypersons should by nature perform worse on a tourniquet application task, based on prior health care experience, adding stress to such task would decrease layperson performance even more. Hence, hypothesis number two was formed.

In order to test this hypothesis, the three tourniquet application performance variables were examined: time to bleeding control, total time application time and performance scores. In accordance with the alternative hypothesis, $H_1$2, laypersons were significantly overall

slower, in terms of time to bleeding control and total time, than professional first responders (both fire rescue and EMS workers). This could mainly be an effect of pure experience but as stated in the prior section, all groups significantly improved their tourniquet application performance scores. As with hypothesis 1, it is possible to interpret these results by comparing it with CPR performance. If CPR performance is worse in the layperson group compared to first responder group, the level of experience could be the explanation. However, no significant group effects were found on any of the three CPR variables, which contrasts with the hypothesis that an effect of group would be found. Two out of the six performance variables showed significant group effects, whereas four did not. In terms of CPR performance, we should keep hypotheses 2, but for tourniquet application this is not necessarily the case. Were professional first responders better on tourniquet application than laypersons? In terms, of speed, yes. In terms of quality, no. In order to answer the question, there would preferably be an answer to the question: which aspect is more important, speed or quality? Since bleeding control is the one thing, by definition, that stops blood loss, the time to bleeding control variable could be seen as the most important aspect of tourniquet application performance. In that regard, we should reject hypothesis 2, and accept the alternative hypothesis, since a group effect was found. The speed versus quality trade-off is a complex question however, since there are several aspects to consider. In the present study, only the C, catastrophic bleeding, in the CABC (or any of its possible variations) algorithm was examined. The CMAST assessment protocol used for performance grading, mostly captures aspects of catastrophic bleeding, but does also cover some aspects relevant for the treatment a patient would receive further down the chain of survival (Cannon, 2018). For example, the CMAST measures if the tourniquet is safe for transport; quickly achieved bleeding control can be crucial if the trauma is severe, but if the tourniquet is not safe for transport it is of no use if the patient must be moved due to circumstances in the proximity. The CAT generation 6 was redesigned to the CAT generation 7 with the speed versus quality trade-off in mind (Clumpner et al., 2013; Kragh, Moore, Aden, Parsons, & Dubick, 2016), where one of the motivations between the redesign was the removal of the double band routing so that the speed of application was increased, which in turn decreased the loss of blood. Going by that logic, we should look at the time to bleeding control variable, instead of the performance score variable. In conclusion, we should reject hypothesis 2 in terms of tourniquet application, and accept the alternative hypothesis, but we should keep hypothesis 2

in terms of CPR performance. This could also indicate that CPR is an easier task than tourniquet application, at least during the circumstances in the present study.

H₀3: Participants across all groups will not experience more stress reactions during the stressful scenario compared to the calm scenario.

H₁3: Participants across all groups will experience more stress reactions during the stressful scenario compared to the calm scenario.

The findings from the tourniquet and CPR performance measurements shows some diverse results. No major decline in performance seems to be linked to the stressful scenario as we would expect. This could either come from the possibility that the stressful scenario in fact was not stressful at all, or not stressful enough for the participants, or as shown in the stress theory section; a stable level of performance can be achieved but at the cost of increased effort or resource allocation, which leads to phenomena such as increased physiological activity, increased workload or higher subjective reports of stress (Hancock & Warm, 1989; Hockey, 1997; Matthews, 2001). As such, there is a need to look at the physiological HR and HRV data, the subjective stress reports from the DSSQ, and the mental workload data from the subjective report of NASA-TLX and the secondary task data.

Starting out with the physiological data. One reasonable explanation for the results of Schreckengaust et al.'s (2014) is that performance decline could simply be an effect of fatigue and physical exhaustion, and not stress in any sense. A typical sign of physical load (muscular strain) is increased heart rate (Ilmarinen, 1984). This is confirmed by the results; heart rate did increase in the stressful scenario from the calm scenario. Whereas heart rate might be more of an overall measure for task demand, the HRV LF band is more sensitive to workload (Aasman et al., 1987). The results show that LF Power did decrease during the stressful scenario, which would indicate that participants were more mentally taxed, hence more stressed. An increased LF/HF ratio have in previously conducted studies been linked to increased levels of stress over a 24-hour period (Sloan et al., 1994), and during acute stress as well (Schubert et al., 2009b), but this was not found in the current study. The relationship between LF Power and the LF/HF ratio is however not completely linear, and different theoretical approaches suggests different assumptions (Hernando et al., 2016), and as such the physiological data are somewhat inconclusive. This will be returned to in the method discussion section. Instead, more obvious markers of stress could be found in the DSSQ and workload data.

The DSSQ was used as an assessment method to capture the subjective reports of stress from the participants. The first meta-factor, task engagement, is related to state constructs

such as focus, motivation and energy (Matthews, 2001; Matthews et al., 2002). The results showed that task engagement increased from the pre-experiment scenario to the stressful scenario across all groups, indicating that the participants felt more focused, motivated and energetic. Low task engagement is typically associated with monotonous vigilance tasks, whereas increased task engagement is usually seen when participants show interest in the task (Matthews, Szalma, Panganiban, Neubauer, & Warm, 2013). But task engagement levels can also be elevated when external stressors are added, such as simulated jet-engine noises (Helton, Matthews, & Warm, 2009). After the experiment several participants reported that during the stressful scenario when the paintball bullets hit the wooden cover, which made loud noises, they felt very stressed, and there were multiple people reporting some sort of "adrenaline rush" when hearing the sound. This can very well be an influencing factor on the task engagement scores. Results of the distress meta-factor from the DSSQ showed that across all groups, distress significantly increased from the pre-experiment scenario to the calm scenario and to the stressful scenario, According to Matthews et al. (2013), workload seems to be the most contributing factor to distress by far, which would naturally explain the increase in distress from the pre-experiment to the calm scenario, since no external (primary or secondary) task was present during the pre-experiment. The worry meta-factor did decrease throughout the experiment for all groups, which according to Matthews et al. (2013) is expected. Worry is typically not as sensitive to task demands as task engagement and distress. Matthews et al. (2013) argues that when working memory is loaded, as it should be while performing the primary and secondary task during the two scenarios, worry levels should go in opposite direction from distress. This pattern was found in the data; distress increased in a seemingly linear fashion, whereas worry declined in a similar linear fashion. This suggests that participants were mentally loaded during the stressful scenario. Noteworthy is that the participants did know before the experiment about the stressful scenario. Verbal utterances of high anticipation and feelings on uncertainty were expressed by the participants. Uncertainty is related to physiological indications of stress (Greco & Roger, 2003). Since people came to the experiment with certain expectations it is possible that the baseline measures from DSSQ were skewed.

Moving on to the workload measurements: NASA-TLX and the secondary task. For the secondary task, the only variable indicating differences between the conditions was the total numbers of errors. During the calm scenarios fewer errors were made, possibly indicating a lower mental demand. The results from the NASA-TLX showed a higher physical demand

scores during the stressful scenario, which is in line with the finding that heart rate was higher during the stressful scenario. Both temporal demand scores as well as frustration scores were lower in the calm scenario, and effort and total NASA-TLX scores were significantly higher in the stressful scenario. This would also indicate that workload was higher in the stressful scenario.

In summary, although performance did not seem to decline during the stressful scenario, other markers of stress were present during the stressful scenario: raised heart rate, decreased LF Power, increased task engagement, increased distress, decreased worry, an increase in errors on the secondary task, and an increase in NASA-TLX scores. The conclusion is that participants across all groups experienced more stress reactions during the stressful scenario compared to the calm scenario, and as such hypothesis 3 should be rejected, and the alternative hypothesis should be accepted.

$H_0$4: Laypersons will not experience more stress reactions than professional first responders during both the calm and stressful scenario.

$H_1$4: Laypersons will experience more stress reactions than professional first responders during both the calm and stressful scenario.

In accordance with the hypothesis by Goolsby, Strauss-Riggs, et al. (2018), the alternative hypothesis 4, $H_1$4, states that laypersons should experience more stress reactions than professional first responders during both scenarios due to inexperience with tourniquets and CPR.

In the physiological data, a significant effect of group on LF Power was detected. Somewhat contrary to $H_1$4, it was fire rescue workers who had a *lower* LF Power than laypersons, possible indicating a higher workload and higher levels of stress. One explanation for this could be the age factor as the mean age was 26 and 39 for the layperson and fire rescue worker group respectively. LF Power have shown to naturally decrease with age for both men and women (G.-M. Kim & Woo, 2011). But another, perhaps more likely explanation based on the other data, is that although fire rescue workers had a higher physical response, they did not seem to experience higher perceived, or factual, stress or workload reactions. The DSSQ results showed that laypersons were more distressed than both fire rescue workers and EMS workers and the same effect was found on worry, where laypersons were more worried than both fire rescue workers and EMS workers. The NASA-TLX scores showed that laypersons reported a higher mental demand, higher effort scores and a higher total NASA-TLX scores than professional first responders. As for the secondary task,

laypersons made significantly more errors than fire rescue workers regardless of condition and task, as well as having a lower percentage of correct answers, both indicating a higher mental workload. The physical reaction in the fire rescue group could then be explained by appraisal theory. Fire rescue personnel works in a physically demanding environment that sometimes could be directly life-threatening (Bos, Mol, Visser, & Frings-Dresen, 2004). The stressful scenario could possibly then be perceived as an "everyday work situation", but without evoking the subjective feelings that is negatively associated with everyday work, such as fear for the own life. Although the data points at the fact that for all groups, the stressful scenario was more stressful in every sense, fire rescue workers seems to have been able to maintain a more stable level of performance on the tourniquet application and CPR tasks, as well as having a lower subjective stress levels, and lower subjective and factual workload levels, but at the cost of increased physiological activity. This in turn would be in line with Hockey's (1997) compensatory control model; when task demands increase and a stable level of performance is maintained, somewhere along the line an increased cost of resources will occur, and in this case it was at the cost of increased LF Power.

In conclusion, laypersons experienced more stress reactions than professional first responders during both scenarios in every aspect (primary task performance, subjective reports in the DSSQ, NASA-TLX scores, secondary task performance) except for LF Power, which instead is explained as a compensatory mechanism.

5.2   Method Discussion

The method used in this study was similar to the method used in the study by Schreckengaust et al. (2014). This study did not show any effects of condition on tourniquet application times, as in the case of Schreckengaust et al.'s (2014) study, and tourniquet application performance scores increased during the stressful scenario. As initially speculated in the previous section, this could have been the result of lack of actual stress in the stressful scenario, but as stated under the section about hypothesis 3, participants did experience more stressful reaction during the stressful scenario. Since Schreckengaust et al. (2014) explained their decline in performance being due to stress, and no such effect could be found in this study, it is possible that the effect found in Schreckengaust et al.'s (2014) study was not due to stress, but something else.

There are some obvious aspects differing between this study and Schreckengaust et al.'s (2014), with the fidelity of the simulated stressful scenarios perhaps being the most prominent

one. The overall fidelity of Schreckengaust et al.'s (2014) study was, regardless of which fidelity we are talking about, most likely higher than in the present study. In Schreckengaust et al.'s (2014) study, for example, a wounded patient was simulated by a human who was laying on the ground displaying discomfort. The stressful scenario in this study was not a combat style scenario in the same regard, although paintball fire was used. Schreckengaust et al. (2014) used a different obstacle running course, performed in pairs of two, where one participant was giving suppressive fire while the other participant applied the tourniquet, which was performed outside in different terrain, such as mud and water, adding another physical aspect to the simulation not present in the current study. Another aspect regarding the scenarios, that could explain differences in the results, is the differences between the calm scenarios and the stressful scenarios, in terms of stress and difficulty; i.e. the calm scenario in the present study was not "as calm" as the calm scenario in Schreckengaust et al.'s (2014) study, although the stressful scenarios could have been equal. The fact that a secondary task was added to the primary tourniquet application and CPR task, raises the question whether the secondary task was too intrusive on the primary task, thus adding a stressor to the calm scenario which was not present in Schreckengaust et al.'s (2014) study. The secondary task was present during the stressful scenario as well, thus it is possible to claim that the stressor effect could be canceled out, but it is not safe to make this claim unless it is confirmed that the secondary task is just as intrusive during the calm scenario as it is during the stressful scenario. This is of course highly speculative and maybe somewhat farfetched, but the point of the argument is, as stated before, that the calm scenario maybe did not differ enough in terms of stress compared to the stressful scenario, in the same manner as it differed in Schreckengaust et al.'s (2014) study. Although this study aimed to replicate Schreckengaust et al.'s (2014) study, it was more of a conceptual replication rather than an exact physical replication. Since stress however, according to the frameworks used in this study, was not measured in Schreckengaust et al.'s (2014) study, speculation is the only thing at hand.

For this study to be important for future research and the results being applicable in real world settings, some aspects of this study should be considered. The first aspect is the tourniquet type itself and the assessment method used. The type of tourniquet becomes a factor when comparing studies to each other. In Schreckengaust et al.'s (2014) study for example, both the CAT and SOFT-T tourniquets were used, and although their results showed similar application times between the tourniquets, it is possible that different types of tourniquet differs in required cognitive demand and effort in different contexts. This matter

becomes important when examining the effects of stress on tourniquet application since if one type of tourniquet affords more errors than other types, during stressful circumstances, recommendations of when and where to use a certain type of tourniquet becomes possible. The effects of stress on one-handed versus two-handed use of the CAT could be a possible future area of study for example.

A major aspect regarding the application assessment in the current study is the lack of confirmation of achieved bleeding control. In this study, bleeding control was graded as achieved if the instructor could not fit three fingers under the tourniquet when Velcro strap was attached to itself, and if the tourniquet was deemed "sufficiently tight" when the windlass was secured. This was purely due to limitation of the manikin, and a recommendation for future studies would be either digital manikin which measures blood pressure, or checking the dorsalis pedis pulse (radial pulse, if applied to the arm) on a real person, such as in Schreckengaust et al.'s (2014) study. Real-time feedback can then be provided, for both the instructor as well as the participant, or in other instances, a learner. In this study the CMAST based assessment template (Lowndes et al., 2017) was used, which was created to assess CAT application and cannot be used to evaluate application of other types of tourniquets. However, the concept of the template could possibly be modified to fit other types of tourniquets as well. The need for a standardized tourniquet application evaluation method goes in hand with the problem of standardized educational guidelines mentioned by Ramly et al. (2016) and Goolsby, Jacobs, et al. (2018). This in turn, raises questions how the results from this study could be translated to a real-world setting. In training, low fidelity is good for novices (Alessi, 1988), but when would a novice on tourniquets be able to apply a tourniquet in a real world scenario? Assessing the transfer effect is out of the scope for this thesis. But, in order to validate whether an educational program is successful or not, one should preferably have an outcome measure related to the real world. And this connects to the point mentioned previously; in order to assess successful bleeding control, a standardized method to do so is needed. A final aspect related to the assessment method is, as mention in the results discussion section, that the CMAST assessment template measures some aspects relevant to the full chain of survival for a patient (Cannon, 2018), and not just catastrophic bleeding. For the purpose of examining immediate bleeding control, all of the template steps are not relevant, but for the purpose of examining if an educational program for layperson is efficient, it serves its purpose well, since steps like "is time noted on the tourniquet?" is important for EMS workers arriving to a scene of an accident, which is important from a holistic viewpoint.

Related to the points above is the educational material used in this study, which was mostly based on the recommendations of Goolsby, Jacobs, et al. (2018). It is very important to note that the recommendations are formed to fit a very large layperson population, hence some of the material was very simplified. For example, Goolsby, Jacobs, et al. (2018) recommended to only discuss the volume and flow of a bleeding, and if the blood volume exceeds half the volume of a regular soda can (150 ml) the bleeding should be considered life-threatening. The idea behind the soda can metaphor was that a layperson easily could estimate the blood volume, since it is a familiar measurement. This assumption can be questioned, since several participants reported after the experiment that they in no way possible could estimate the volume of half a soda can poured on the ground. From the professional group, participants also reported that they would not consider a loss of 150 ml of blood life-threatening, and hence did not mark that as the correct alternative on the knowledge-based questions. Standardization is by pragmatic means necessary, but as exemplified by the soda can metaphor, it can also be confusing. One of the three aspects that an educational bleeding control program should achieve according to Goolsby, Jacobs, et al. (2018) was to motivate learners, the current study showed that opinion towards tourniquet usage did increase, and future studies should also include this measure, as well as examine the relationship between tourniquet performance and opinion on tourniquet usage and self-assessed tourniquet application ability.

For the physiological measurement, a commercially available heart rate monitor was used to measure HR and HRV, the method was chosen since the device could be used seemingly everywhere without any cables connected. HR and HRV are only two of many physiological indications that can be used to assess stress. Other methods exists such as electroencephalography (Fairclough & Venables, 2006) and cortisol levels (McEwen, 2008), and should be considered if using a similar study design to this one. The use of HRV as marker of stress is also debatable, especially the use the LF Power band, and the LF/HF ratio. A decrease in LF Power have been used as a physiological indicator of stress and increased workload in some studies (Boucsein & Backs, 2000), but another study for example suggests that an increase in LF Power is expected when workload increases (Bernardi et al., 2000). Visnovcova et al. (2014) showed that LF Power is sensitive to different types of cognitive tasks, showing both increases and decreases in LF Power, depending on the type of the task.

This inconclusiveness in the findings suggests a careful examination on the type of the tasks performed during HRV measurements; i.e. it is not enough to say that LF Power

increases or decreases during increased workload, other workload related concepts of workload must be specified as well. One of the reasons why the inconclusive results exists is because of uncertainty of what LF Power exactly measures. Even if LF Power would mainly reflect SNS activity, it is still partially driven by PNS activity (H.-G. Kim et al., 2018), and the question is whether this "mainly" is enough to make LF Power a reliable measure of stress and workload. The early rationale behind the LF/HF ratio was that LF Power was a measure of SNS activity, and HF Power a measure of PNS activity, and hence it was called measure of sympathovagal balance (Billman, 2013). However, research have shown that heart rate influences HRV, which means that a low LF/HF ratio due to low LF Power would tell us something, whereas a low LF/HF ratio due to high LF Power would tell us something completely different (von Rosenberg et al., 2017). In other words, when examining HRV data, one must take into consideration the task was performed during rest or physical load. One limitation of the current study was the lack of distinction in physiological reactions between the two primary tasks, tourniquet application and CPR due to practical limitations. A future study should focus on differentiating the two tasks in terms of HR and HRV. If the two tasks for example differ in HR, and the HR data then is compared to LF Power, the influence of physical load on LF Power could then be examined, which also would tell us how physiological reactions is linked to other measurements such as those used in this study: DSSQ, NASA-TLX, or tourniquet application and CPR performance. This would increase reliability for the study.

A final remark is made regarding the sample population itself. One factor not controlled for in the statistical analysis was age. Mean age was higher for both fire rescue workers and EMS workers compared to laypersons. Physical ability has shown to decline with age (Samson et al., 2000) which could be an alternate explanation to the fire rescue workers showing a lower LF Power. The EMS worker group was small (n=11), and future research should expand the sample size for this group. In terms of sample bias, it is possible that since participants knew beforehand about the stressful scenario, only participants willing to being exposed to pain stimulation would participate. This sample bias have been shown in pain research in a recent article by Karos, Alleva and Peters (2018), and as such, this sample may not reflect the population as a whole Related to this is the possibility that the DSSQ results were affected by this as well. Several participants came to the experiment with different anticipations. Some described themselves as "amped up" when arriving at the experiment. Thus, the baseline measurement for the DSSQ might have been skewed from the start, and

participants could have a higher HR during the calm scenario than they would have during normal circumstances (i.e. not having thoughts about pain stimulation in their head).

In summary; this study was not an exact replication of Schreckengaust et al.'s (2014) study, although the most conceptual aspects were kept. Stress was also measured physiologically, subjectively and with performance measures, thus making this study more reliable in terms of stress measurement. Recommendation for future studies are examining the fidelity of the hemorrhage control scenarios, validating the tourniquet performance assessment method, examining the relationship between tourniquet application ability and self-assessed tourniquet performance ability, testing different physiological measurement methods of stress and replicate this study with different sets of sample sizes, whilst controlling for sample bias.

6 Conclusion

In conclusion, the purpose of this study was to investigate how the performance of two first aid interventions, tourniquet application and CPR, was affected by stress in immediate (layperson) and first (professional) responders. In accordance with current research about tourniquet usage in pre-hospital settings, along with some major stress frameworks, four pairs of hypotheses were formed:

- **$H_0 1$**: Tourniquet and CPR performance will be equal during the stressful scenario and the calm scenario across all groups.

- **$H_1 1$**: Tourniquet and CPR performance will be lower during the stressful scenario compared to the calm scenario across all groups.

- **$H_0 2$**: Laypersons tourniquet application and CPR performance will be equal to the performance of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.

- **$H_1 2$**: Laypersons tourniquet application and CPR performance will be lower than that of professional first responders, in terms of application time and quality (tourniquet) and quality (CPR), during both calm and stressful circumstances.

- **$H_0 3$**: Participants from all groups will not experience more stress reactions during the stressful scenario compared to the calm scenario.

- **$H_1 3$**: Participants from all groups will experience more stress reactions during the stressful scenario compared to the calm scenario.

- **$H_0 4$**: Laypersons will not experience more stress reactions than professional first responders during both the calm and stressful scenario.

- **$H_1 4$**: Laypersons will experience more stress reactions than professional first responders during both the calm and stressful scenario.

Hypothesis 1, $H_0 1$, should not be rejected since tourniquet application performance did not decrease as expected during the stressful scenario, instead tourniquet application performance scores *increased.* Only one CPR performance variable declined during the stressful scenario. This is not sufficient to say that overall performance declined. This is contrary to the study by Schreckengaust et al. (2014). Hypothesis 2, $H_0 2$ was not rejected in terms of CPR performance since no effect of group on CPR performance was found. But for tourniquet application times, fire rescue workers were significantly faster than laypersons and

as such the hypothesis should be rejected in that regard, and the alternative hypothesis should be accepted. For hypothesis 3 convincing results showed that participants across all groups did experience more stress reactions as shown by raised heart rate, decreased LF Power, increased task engagement, increased distress, decreased worry, an increase in errors on the secondary task, and an increase in NASA-TLX scores during the stressful scenario compared to the calm scenario, which leads to rejecting hypothesis 3, H_03, and accepting the alternative hypothesis. This would also lead us to the conclusion that the effects of stress on tourniquet application performance found in Schreckengaust et al.'s (2014) study was not due to stress. The final hypothesis 4, H_04, was also rejected, and the alternative hypothesis accepted; laypersons did experience more stress reactions than professional first responders during both scenarios in every aspect (primary task performance, subjective reports in the DSSQ, NASA-TLX scores, secondary task performance) except for LF Power.

Experienced stress was assessed using multiple methods in accordance with several theoretical frameworks of stress, but room for improvements are suggested, such as: examining the fidelity of the hemorrhage control scenarios and testing how different levels of fidelity affects performance, validating the tourniquet performance assessment method, examining the relationship between tourniquet application ability and self-assessed tourniquet performance ability, as well as examining the transfer-of-training effect of hemorrhage control training into a real-world setting. Recommendations about testing and validating physiological measurement methods of stress (HR and HRV) are also made. A replication of this study with different sets of sample sizes, whilst controlling for sample bias, and testing whether the type of tourniquet have any effects on performance and cognitive workload, would also be necessary in order to test the reliability of the method used in this study.

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Appendix

Tourniquet assessment template

Korrekt utfört	Ej korrekt utfört	Steg	Eventuell kommentar
		1. Tourniqueten applicerad minst 5 cm proximalt från skadan (mellan skada och bål). "High & tight" är också godkänt. Över led är ej godkänt.	
Avstånd från skadan: _____ cm			
		2. Spännremmen är ordentligt åtdragen och säkrad med kardborre. (Man kan ej få in två fingrar mellan)	
Ange mått för åtdragen spännrem: _____ cm			
		3. Spännarmen ordentligt åtdragen så att pulsen nedom skadan upphör (och blödningen slutar).	

Ange antal varv för spännarmen:

		0	0.25	0.75	1.25	1.75	2.25	2.75	3.25	3.75
	Medurs									
	Moturs									

Korrekt utfört	Ej korrekt utfört	Steg	Eventuell kommentar
		4. Spännarmen säkrad i kroken	
Anteckna tid för steg 1-4: _____ sekunder			
		5. Spännremmen är dragen över spännarmen	
		6. Kardborre-biten är applicerad över kroken för att säkra spännremmen	
		7. Tid är noterad på kardborre-biten	
		8. Tourniqueten är applicerad tillräckligt säkert för transport	
Anteckna total tid (steg 1-8): _____ sekunder			