UMEÅ UNIVERSITY

Knowing What's Going on

– situation awareness and team performance in interprofessional teams

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"If you want to go fast, go alone.
If you want to go far, go together"

African Proverb

To my family with love

Table of Contents

Table of Contents **iii**
Abstract **iv**
Svensk sammanfattning **vi**
Original papers **ix**
Abbreviations **x**
Preface **xi**
Introduction **1**
Background **2**
Patient safety 2
Non-technical and technical skills 3
Learning and simulation-based (team) training 9
Rationale **13**
Aims of the thesis **14**
Specific aims 14
Materials and Methods **15**
Setting 16
Participants 16
Measurements 18
Data analyses 27
Ethical considerations 29
Results **30**
Discussion **36**
Methodological considerations 40
Conclusion and implications for practice 44
Further research 45
Acknowledgements - Tack **47**
References **49**

Abstract

Background Within critical care, it is necessary to have an awareness of what is going on in order to be able to make the right decision at the right time. Situation awareness (SA) is a non-technical skill (NTS) that is important in stressful, complex environments such as the intensive care unit (ICU). Deficiencies in NTS are well known to impact performance and thereby cause adverse events. More knowledge about how background factors are associated to team performance and explore critical care team members experiences teamwork are of importance to develop models for improving teamwork. An educational intervention aiming to improve SA during critical events might be valuable to improve the performance of interprofessional teams. For this, instruments for assessment of SA and NTS are needed.

Aim The aim of this thesis was to test different instruments for measuring SA, team performance and task performance for feasibility and reliability; to investigate the relationship between team background characteristics, team performance and task performance; to evaluate an educational programme in SA for intensive care teams; and to explore team members' experience of teamwork.

Methods This thesis was based on data from 69 different video-recorded team training sessions with a simulator as a patient (studies I–III) and nine focus group interviews (Study IV). In Study I, the participants were 55 medical students, and the sessions took place at a clinical training centre. The participants in Study II (n=105) and III (n=75) were ICU staff members from two different hospitals, and the sessions took place *in situ* at the respective ICUs. In Study III, the participants were randomized into control or intervention group, where the intervention group received an educational intervention comprising lectures and reflective discussions. The control group only performed team training without lectures and reflective discussions. The training sessions were analysed with a focus on team and task performance using the TEAM instrument and the ABCDE checklist, respectively. In addition, a questionnaire (SAGAT) was used to assess individuals' SA (Study I and III). The data in Study I–III were quantitatively analysed. In Study IV, focus group interviews with staff members (n= 31) from the ICUs were analysed using qualitative content analysis.

Results The findings in Study I showed that SAGAT was feasible to use and that the inter-rater reliability for the ABCDE checklist and the TEAM instrument indicated sufficient stability. In Study II, higher *age* was associated with several aspects of good team performance such as teamwork, task management, team overall and total team. *Prior team training without video* was associated with better task performance, while *prior education in communication* was negatively associated with leadership. In Study III, the results demonstrated that the educational intervention improved the performance of the intervention group in the TEAM subscales of leadership and task management, as well as in the total score. In Study IV, the main finding presented as a theme was *balancing knowledge and behaviour in teamwork*. The interviews revealed three categories of aspects that facilitate

or act as barriers to teamwork: (1) having potential for excellence while coping with members who do not act as team players; (2) creating a safe atmosphere while working in an unknown environment and struggling to maintain one's positions; and (3) being in a workflow without becoming overwhelmed.

Conclusions By implementing an educational programme focusing on SA, different parts of interprofessional team performance could be improved. For optimal interprofessional teamwork in the ICU, both knowledge and behaviours were essential components. For the studies in this thesis, the different instruments used were both feasible and reliable. High age was related to good team and task performance, indicating that generic factors that is associated with age might influence team and task performance.

This thesis will probably contribute to a safer care of seriously ill patients at ICU.

Keywords Critical care, interprofessional education, leadership, learning, situation awareness, simulation-based team training, team performance, teamwork

Svensk sammanfattning

Att veta vad som händer vid akuta situationer inom intensivvård av svårt sjuka eller skadade är nödvändigt för att kunna ta rätt beslut vid rätt tidpunkt. Arbetsmiljön på intensivvårdsavdelningar (IVA) beskrivs därför som komplex och kräver välutbildad och erfaren personal. Brister i icke-tekniska färdigheter är ett problem i hälso- och sjukvården och inte minst inom intensivvården. Bristerna påverkar kvalitén i utförandet och orsakar vårdskador. Utifrån erfarenhet och kunskap inom flygindustrin har icke-tekniska färdigheter börjat komma i fokus inom akutsjukvård och intensivvård. En viktig del i icke-tekniska färdigheter är situationsmedvetenhet (eng; situation awareness, SA) och under de senaste årtiondena har modeller för SA och teamarbete utvecklats. I dagsläget finns endast ett fåtal studier som specifikt utvärderar utbildning i SA i interprofessionella team, *in situ* och med hjälp av simulering. Föreliggande avhandling har därför fokus på interprofessionella IVA-team, SA och teamprestation och förmåga att hantera och genomföra arbetsuppgifter.

Avhandlingen omfattar fyra delarbeten. För att genomföra studie II och III krävdes en initial studie (studie I) vars syfte var att kvalitetssäkra tre mätmetoder avseende användbarhet och reliabilitet: dels en teknik för att mäta situationsmedvetenhet (SAGAT), dels ett instrument för att mäta teamets prestation (TEAM instrument) och dels en checklista för att mäta teamets förmåga att hantera arbetsuppgifter (ABCDE checklist). Därefter analyserades relationen mellan teamets bakgrundskaraktäristika och teamets prestation och hantering av arbetsuppgifter (studie II). I studie III utvärderades ett utbildningsprogram med fokus på SA inklusive simuleringsövningar *in situ*. För att få en djupare förståelse för fenomenet teamarbete inom IVA, genomfördes en intervjustudie där tre personalgrupper som vanligen ingår i IVA-team intervjuades med fokus på erfarenheter om teamarbete.

Deltagarna i delstudie 1 var 55 läkarstudenter på termin sju som fördelades i 23 team. De två följande delstudierna (II och III) omfattade undersköterskor (n=30), sjuksköterskor (n=49) och läkare (n=26) som arbetade vid två intensivvårdsavdelningar vid två olika sjukhus i norra Sverige. Deltagarna i studie III delades slumpmässigt in i 11 team (interventionsgrupp) respektive 9 team (kontrollgrupp). I delstudie IV deltog 31 individer från delstudie II och III fördelade på nio fokusgrupper.

Interventionen i delstudie III utgjordes av ett kort utbildningsprogram med fokus på att förstå betydelsen av situationsmedvetenhet i teamarbete samt hur den kan uppnås. Den första delen av utbildningen var webbaserad med korta lektioner om situationsmedvetenhet och samarbete varvat med instuderingsuppgifter och reflektionsfrågor. Deltagarna genomförde utbildningen individuellt en vecka före teamträningstillfället. Teamträningstillfället för interventionsgruppen inleddes med en reflektionstimme där olika reaktioner från webutbildningen diskuterades med fokus på hur de olika begreppen skulle omsättas i praktiken. Därefter genomförde teamet ett patientscenario *in situ,* på en intensivvårdsplats. Efter

scenariet återsamlades teamet för en andra reflektion med fokus på hur teamet kan åstadkomma och bibehålla hög situationsmedvetenhet för att gemensamt kunna fatta rätt beslut. Teamträningen avslutades med ytterligare ett patientscenario *in situ*. Kontrollgruppen teamtränade utan att ha genomfört webutbildningen, utan reflektionen före scenario nummer ett, samt att reflektionen efter scenario nummer ett genomfördes utan specifikt fokus på situationsmedvetenhet.

Vid datainsamlingen till studie I-III genomförde deltagarna teamövningar innefattande olika scenarier med svårt sjuk patient (SimMan, en avancerad patientsimulator). Samtliga teamövningar videofilmades och analyserades avseende teamets samarbete och genomförande av arbetsuppgifter. I studie I och III mättes deltagarnas situationsmedvetenhet med frågeformulär under scenariet. Ett kort uppehåll gjordes där deltagarna svarade på frågor. En vecka efter avslutad övning fick deltagarna i studie I besvara en enkät om hur avbrottet påverkat det pågående scenariet. Data från dessa tre första studier analyserades med hjälp av statistiska metoder. Datainsamlingen till studie IV genomfördes med fokusgruppsintervjuer. Intervjuerna ljudinspelades och analyserades med kvalitativ innehållsanalys.

Resultatet från studie I visade att det fanns en god samstämmighet mellan de fyra bedömare som skattade teamets prestation. Med hjälp av ett frågeformulär angav studenterna att tekniken som användes för att mäta teamets situationsmedvetenhet var användbart och användarvänligt.

Resultatet i delstudie II visade att det fanns ett positivt samband mellan genomsnittlig ålder och teamets övergripande prestation och samarbete, samt hur teamet prioriterade och hanterade arbetsuppgifter. Vidare visade resultatet att tidigare erfarenhet av att ha tränat i team också innebar bättre förmåga att hantera arbetsuppgifterna. Däremot visade analyserna att tidigare utbildning i kommunikation också innebar sämre ledarskap.

Huvudresultatet i denna avhandling visar på positiva skillnader i prestation hos team som fått utbildning med fokus på situationsmedvetenhet jämfört med kontrollgruppen som inte fått utbildning. De team som erhållit utbildning presterade bättre. Förbättringen kunde mätas i subskalorna ledarskap och prioritering av arbetsuppgifter. Inga skillnader kunde dock påvisas i situationsmedvetenhet eller i genomförande av arbetsuppgifter.

I fokusgruppsintervjuerna (delstudie IV) beskrev deltagarna sina erfarenheter av teamarbetet i det interprofessionella teamet som bestod av både främjande och hindrande aspekter: 1) att ha potential för excellens och samtidigt hantera teammedlemmar som inte agerar som lagspelare, 2) att skapa en säker atmosfär och samtidigt arbeta i en okänd omgivning och kämpa för att upprätthålla sin position i teamet, samt 3) att vara i ett flöde av arbetsuppgifter utan att bli överbelastad. Av kategorierna framgår att fenomenet teamarbete handlar om att balansera kunskap och beteende vilket också bildade temat i delstudien. Deltagarna upplevde att det var viktigt att arbeta i en trygg miljö som präglades av respekt och stöd på intensivvårdsavdelningen men även när de arbetade på exempelvis

akutmottagningen. Det framkom också att även om arbetet kunde upplevas stressigt och rörigt kunde det ändå finnas ett flyt.

Sammantaget bidrar avhandlingens resultat till att visa att en utbildning med fokus på situationsmedvetenhet kan förbättra hur team inom intensivvården presterar. Vidare har balansen i kunskap och beteende lyfts fram som viktigt för samarbetet inom teamet. De instrument som använts för att mäta deltagarnas prestationer och situationsmedvetenhet var tillförlitliga och användbara i denna kontext. Slutligen fanns ett positivt samband mellan hög ålder och god teamprestation, samt till genomförande av arbetsuppgifter. Detta samband fanns inte till yrkeserfarenhet vilket antyder att det i bakgrunden skulle kunna finnas någon icke teknisk färdighet som samvarierar med ålder.

Nyckelord Intensivvård, interprofessionellt samarbete, ledarskap, lärande, situationsmedvetenhet, simuleringsbaserad teamträning, teamprestation, samarbete

Original papers

This thesis is based on the following papers, which will be referred to in the text by their Roman numbers:

I Hultin, M., Jonsson, K., Härgestam, M., Lindkvist, M., Brulin, C. **(2019). Reliability of instruments that measure situation awareness, team performance and task performance in a simulation setting with medical students.** *BMJ Open, 9(9), e029412. https://doi.org/10.1136/bmjopen-2019-029412*

II Jonsson, K., Hultin, M., Härgestam, M., Lindkvist, M., Brulin, C. **(2020). Factors Influencing Team and Task Performance in Intensive Care Teams in a Simulated Scenario.** *Simulation in Healthcare: Journal of the Society for Medical Simulation, Publish Ahead of Print. https://doi.org/10.1097/SIH.0000000000000462*

III Jonsson, K., Brulin, C., Härgestam, M., Lindqvist, M., Hultin, M. **(2020). Do team and task performance improve after training situation awareness? An in situ simulation team training randomized controlled study of interprofessional intensive care teams.** *Submitted*

IV Jonsson, K., Hultin, M., Brulin, C., Härgestam, M. **(2020). Balancing between knowledge and behaviour in teamwork - experiences in interprofessional ICU teams.** *Manuscript*

Papers I-II have been published and are reprinted by kind permission of the respective journals.

Abbreviations

AE	Adverse event
CCRN	Critical care registered nurse
CRM	Crisis resource management
CTC	Clinical training centre
GDTA	Goal-directed task analysis
EN	Enrolled nurse
ICU	Intensive care unit
NTS	Non-technical skills
MD	Medical doctor
PSQ	Post-simulation questionnaire
SA	Situation awareness
SAGAT	Situation awareness global assessment technique
SBT	Simulation-based training
SBTT	Simulation-based team training
TS	Technical skills
TSA	Team situation awareness
TSAGAT	Team situation awareness global assessment technique

Preface

Growing up in the north of Sweden my initial plan in life was to become a teacher in sports. Unfortunately, or fortunately, moving 330-miles south was too far from my family and friends so instead I graduated as a registered nurse at Umeå University. Since then, I have always felt a passion for the critical care context - one inspiring teacher at the university was 'to blame'. She was a nurse in anesthesia and did a good job marketing the critical care profession. I have now spent almost two decades mostly working in emergency departments and intensive care units. This field is constantly developing, never lacks challenges, and is extremely rewarding; and while I realize that I have learned a lot, I still have a lot to learn. Working in interprofessional teams and solving complex situations for critical patients is highly satisfying. I also feel enormously lucky to have had the chance to combine my work as a nurse within the intensive care unit with the Aeromedical Services, University Hospital of Umeå, and to also be part of the Swedish National Air Medivac, SNAM. The manager of the Aeromedical Services, has always tried to inspire and stimulate us to think outside the box. In 2009 he invited an experienced pilot who was responsible for security and leadership education within aviation to give a lecture. This pilot talked to us about how he educated individuals on the subject of human factors which instantly caught my attention. That same year I became an instructor for simulation-based team training and since then I have also been involved in the education of new instructors.

I left the multifaceted full-time role of registered nurse nine years ago when I was offered a job at the university. Thereafter, I spent the majority of my time with students, but still kept one foot in the intensive care and air ambulance world. That combination has deepened my knowledge in both education and clinical practice on many levels.

Situation awareness has been described as 'the engine that drives the train for decision making and performance in in complex, dynamic systems' [1]. During my time as a team training instructor, I observed that solutions for obstacles are often present within the team, but these solutions could be hard to locate or enact in the moment. When the opportunity to undertake doctoral studies on the topic of team training presented itself five years ago, I knew that I could not miss this chance! The underlying question that inspired my research was therefore to identify difficulties in teamwork and see if improvements could be achieved by implementing situation awareness.

Introduction

In general, it is common for incidents to occur in healthcare, and a significant proportion are related to human factors. In fact, up to 50% of adverse events (AEs) in healthcare are preventable [2], and medical errors are the third leading cause of death in the United States [3]. At intensive care units (ICU), 58% of patients have experienced one or more events whereof 34% were AEs [4]. Because ICU patients are seriously ill or injured, working in the ICU involves carrying out a high workload in a technical and complex environment. Therefore, ICU patients meet specialized intensive care personnel working in interprofessional teams. Although ICU care has developed during the last decade, ICU patients are at high risk of suffering from AEs [5-6] caused by medical errors. According to a 2010 study on drug administration, lack of guidelines and human error, the majority of medical errors in the ICU are preventable [7]. These circumstances indicate the importance of developing patient safety processes in interprofessional care in the ICU.

Patients' outcomes are positively related to healthcare professionals' level of expertise and ability to understand patients' state and make the right decisions. In addition, in a complex environment such as in critical care, many decisions must be undertaken under time pressure [8]. Situation awareness (SA), which is one of the non-technical skills (NTS), is described as being able to assess the situation, perceive important factors in the environment, comprehend the meaning of such factors and project the near future [9]. Safety, communication, teamwork and environment are critical factors to obtaining SA [10]. Teamwork – especially in complex environments – depends on the team's SA [11-13]. On the other hand, a team's SA depends on the mental models of the different team members, which may be challenged by both environmental and individual factors [14]. Team performance depends on functional teamwork and individual task skills. Without SA, it is impossible to perform appropriate actions, which will impede team performance. Without teamwork, it is impossible to obtain a shared team SA. Thus, SA is interconnected with teamwork in a reinforcing circle; in order to optimize team performance, both components must be taken into account.

In order to enable ICU teams to better prepare for preparedness (and to understand better how to best prepare teams for working) in a complex environment, this thesis will focus on SA and its relation to team performance. First, the instruments used in this thesis needed to be tested for trustworthiness (Study I). Next, it was important to understand the relationship between team members' background characteristics and team and task performance (Study II). This knowledge was necessary to evaluate an educational programme focusing on SA (Study III). Finally, in order to obtain a deeper understanding of the components that influence SA and teamwork, interprofessional team members' experiences were examined (Study IV). My intent was to use several different methods to understand and obtain further knowledge about NTS, with a focus on SA and its impact on team and task performance. The knowledge of SA generated by this research has the

potential to improve team and task performance in a critical situation and most likely improve patient safety as well. As it is based on my clinical experiences from working in both teams and training teams, I hope that this thesis will emphasize SA as a key knowledge for improving team and task performance within complex environments such as the ICU.

Background

This section starts by presenting an overview of important concepts. It then defines and describes patient safety and discusses how it can be improved and promoted. Next, the current status of NTS will be presented, including: (1) technical skills (TS); (2) the concept of crisis resource management (CRM); (3) SA and its theory, education, implications and measurements; and (4) theories about and descriptions of team and task performance. Finally, theories about learning and the application of simulation-based training (SBT) are described.

This thesis in the medical sciences has its basis in nursing [15-16]. Nurses have a central role in providing safe care, improving patient safety, learning and educating colleagues, measuring and providing patient safety, involvement in organizations, and being the voice of patients and relatives [15-18]. When things go wrong in complex environments, such as the ICU, the reasons are most often related to NTS and involve human factors. In order to improve NTS, the team's and/or team members' ability to achieve SA must be trained, using SBT, for example. To prevent medical errors, training and learning in a simulation-based context is an established and successful method in the healthcare context [19].

In this thesis theories on teams and pedagogical theories about learning are included in parallel to theories about SA. These theories complement each other within the wide concept of nursing and are described in each section.

Patient safety

Patient safety is of the outmost importance in medicine, healthcare and nursing around the world. The World Health Organization (WHO) describes patient safety as "a healthcare discipline that emerged with the evolving complexity in healthcare systems and the resulting rise of patient harm in healthcare facilities" [20]. In Sweden, patient safety is described in the law of patient safety [21], which aims to promote high levels of patient safety in Swedish healthcare. Vincent and co-workers [22] have described patient safety in terms of identifying a structure and process for preventing AEs in patients caused by diseases and/or procedures within healthcare. Awareness of the importance of patient safety has dramatically increased since the publication of the Institute of Medicine's 1999 report [23] titled *To Err is Human: Building a Safer Health System*. At that time, the number of incidents of death caused by medical errors and AEs was 100 000 patients per year in the United States. Recently, the Swedish Board of Health and Welfare reported that medical errors in healthcare are often caused by a lack of

competence, shortages in staffing and a high workload. These risks are reinforced by defective transmission of information and communication, a lack of SA, incorrect prioritization or inadequate monitoring. In Sweden, AE cost more than 8 billion SEK, affect 100 000 individuals and are a contributing factor to 1200 deaths each year [18, 24].

An AE has been defined as an unintentional injury caused by medical management instead of the patients' underlying disease [25]. In medical care, AEs are common and are often related to problems with team performance. They are often caused by latent failures such as time pressure, fatigue and understaffing; in work environments and organizations, they are also caused by active failures such as mistakes and procedural violations [26]. Both nurses and physicians describe a high workload and communication failures as substantial risks for deteriorated patient safety as a result of AEs [27]. AEs mostly lead to prolonged hospitalization [28], which affects both the individual and society's economy. As Rodziewicz and Hipskind [28] have pointed out, AEs are preventable. To prevent AEs, patient safety in critical care must be improved. For example, Manser [29] identified the relationship between communication and teamwork failures, decreased patient safety, and a lack of validated team performance. In a report by Johnson and Kimsey [30], improved teamwork was related to increased patient safety and improved team performance. Another critical component in improving patient safety might be to change the workplace culture and work environment by focusing on the systematic training of NTS instead of focusing only on knowledge and TS [31]. Thus, to improve patient safety, a theoretical education in how to achieve safer healthcare in combination with training in interprofessional teams must be implemented early in medical education [32]. Flin [33], Gordon [34] and Jones [35] have reported that although a focus on and education in NTS improved patient safety, theoretical models – to be specific, reports of interventions and measures of patient outcome – are lacking [34]. This thesis therefore focuses on education in, training on and learning NTS in ICU teams, while working in a complex environment, in order to optimize team performance and – in the end – patient safety.

Non-technical and technical skills

According to an international expert panel [36], NTS are defined as *"*a set of social (communication and teamwork) and cognitive (analytic and personal behaviour) skills that support high quality, safe, effective and efficient interprofessional care within the complex healthcare system*"*. Thus, NTS cover skills such as SA, decision-making, communication, teamwork, leadership, managing stress and coping with fatigue. These skills are important for using work-related abilities, utilizing technical knowledge and understanding how to perform tasks [37]. Improving NTS is likely to improve patient safety in critical settings as well. In addition to NTS, effective teams need to share knowledge and proficiency in performing TS [38]. TS are described as "the adequacy of the actions taken from a medical and technical perspective" [39]. Training and learning TS is time consuming, involves several steps in developing from a beginner to an expert, and incorporates both motor-learning skills and psychological components [40-41]. Fast

technological advances in complex clinical environments that place a high demand on efficiency, skills and task performance increase the need for the systematic training of TS [42]. These skills can be trained in a simulated context without compromising patient safety [43]. The focus of this thesis is on NTS such as SA and team performance, the latter of which includes teamwork, leadership and task management. One study [44] reported that a lack of NTS – mostly a lack of SA, teamwork and decision-making – caused death in almost half of fatal medical accidents. Mandatory NTS training and education over a two-year period for surgical trainees, who were evaluated using objective structured clinical examination (OSCE), resulted in significant improvements in, for example, the disclosure of errors [45]. In addition, participants were found to have increased knowledge of NTS, including and understanding that NTS is now validated and applicable for mandatory education and training in surgery [46] and in nursing [47].

CRM is a significant concept and strategy in NTS. CRM was initially developed for aviation and the military, and entered healthcare after positive effects had been observed [48]. In healthcare, CRM has been used for improving team performance and for handling and resolving critical incidents in a simulated environment [49-50]. Today, CRM is used within team training in healthcare for optimizing performance, identifying AEs and preventing errors, standardized communication, handling stress, achieving common goals and decision-making, flattening hierarchy, give-and-take feedback and reaching a high level of SA [51- 52]. In Sweden, studies have indicated that CRM affects the staff's awareness regarding patient safety [53]. Evaluating the effectiveness of CRM training is complex, as it depends on different learning objectives. Only a small number of studies show results at the level of patient outcomes. In contrast, there is more abundant literature on improvements in reactions, knowledge, skills and attitudes after training with CRM in SBT [54]. The evidence based TeamSTEPPS programme [55] includes communication tools for improving teamwork. A recent review evaluating the programme has shown that learning principles with pre- and post-tests and systematic training in communication reduces the frequencies of errors and induce desirable behavioural changes. [56]. Patient outcomes are more difficult to evaluate; however, some studies have demonstrated beneficial patient and economic outcomes related to a shorter time being spent in the emergency department and operating room [57]. The project analysed in this thesis involved an intervention that consisted of targeted education for healthcare professionals working in the ICU at two Swedish hospitals. The main focus of this educational programme was SA, but it also included a theoretical discussion of NTS and CRM. The goal of the project was to impact the behaviour of teams working in the ICU.

In this thesis, NTS includes SA and team performance, while TS includes task performance. This thesis presents the overall hypothesis that education and training in NTS, such as SA, improves team and task performance (Study III).

Situation awareness

In this thesis, Endsley's [58] theory of SA is used. According to Endsley, SA is "knowledge about what is going on around you" and is defined as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future".

SA is important in every setting in which humans are involved in complex environments. Within NTS, SA may be the least understood construct, even though it is the most important human factor [59]. According to Endsley [58], SA is a cognitive model with three levels: (1) *perception,* which is fundamental in forming a picture and obtaining information about a situation; (2) *comprehension,* which consists of a subjective interpretation and an understanding of the significance of the information; and (3) *projection*, which is the ability to forecast future events, anticipate and plan. Projection is also the step that comes before decision-making (Figure 1). The highest level of SA corresponds to an individual's ability to predict future events. SA is multifaceted, since it includes different cognitive levels and processes, and is a picture of the individual's mental model. SA is necessary for people to find, sort and analyse data, and is necessary in order for people to perform tasks effectively. People with a high SA are better prepared to know what is going to happen and are therefore better prepared to act [58].

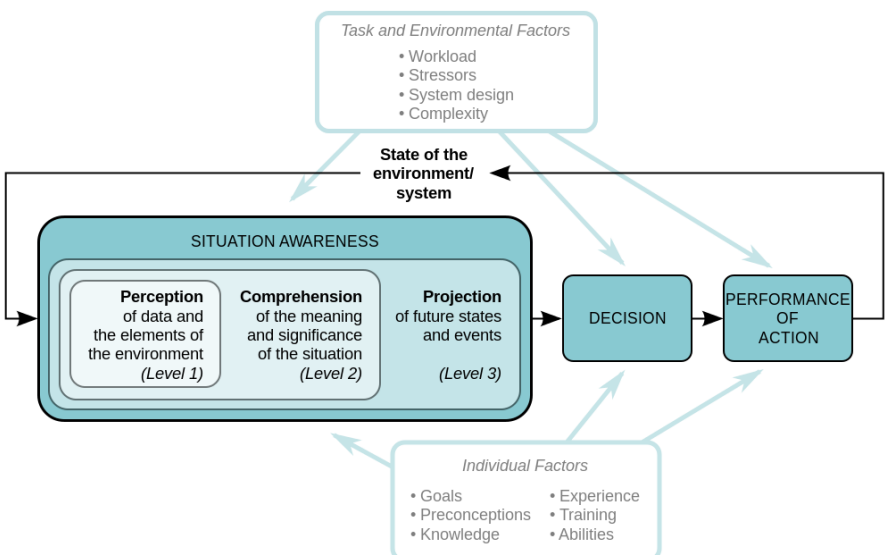

Figure 1. *Endsley's model of SA as outlined in several sources, notably Endsley [58] and Endsley et al. [70].*
(Diagram drawn by Dr. Peter Lankton, May 2007

This theory states that SA is related to individual factors such as working and long-term memory. SA is affected by changes and an unstructured workload. Furthermore, there is a difference between incorrect SA and low SA, which is described as "being wrong versus being uninformed" [60]. Healthcare professionals differ in terms of SA, ranging from novices to experts. For beginners (i.e. novices), SA is demanding and incomplete; in contrast, experts evolve and form more developed mental models [14]. SA has been suggested to be necessary for a correct and effective decision-making process and for performing actions, especially in critical situations [61-62].

A correct decision-making process is important for the outcome of patient care in everyday healthcare work. To make the right decision, it is essential to have knowledge about what is going on with the patients; therefore, SA is crucial in preventing critical situations [62]. It has been found that a loss of SA is a common reason for medical errors and AEs in critical care [63- 64]. To enhance SA, the different challenges and obstacles in the three levels of SA, which cause different types of errors, must be taken into consideration. At level 1, errors are caused by failing to perceive the right information or having inaccurate information, hidden key information, monitor failures and so forth. In level 2, errors are caused by cues and information not being integrated and understood correctly, while errors in level 3 stem from incorrect or not fully understood predictions of future events [61]. In a German anaesthesia closed claims analysis of death and brain damage, Schulz and co-workers [63] stated that 74% of anaesthesiologist errors were caused by the loss of SA. Of these, 42% were caused by failures in SA at level 1 (perception). According to Endsley [14], high workload, fatigue and stress increase the risk of failure in SA levels 1 (perception) and 2 (comprehension). Moreover, confirmation bias, which is one example of an SA challenge, has been described as being stuck within the wrong mental model, as individuals hand-pick information that supports their theory [59, 65]. Parush [66] points out the importance of information sharing to achieve a collective understanding of the situation for everyone in the healthcare team.

Based on SA, Salas [67] developed the concept of team situation awareness (TSA), which comprises the team's entire set of knowledge and expectations for the team task, as well as the team's understanding of the situation. TSA is influenced by the individuals in the teams, their verbal communication and the information obtained from displays; consequently, TSA will vary over time. In a study [68], TSA was described as a critical factor in complex environments, and better TSA was correlated with better team performance. Overall, TSA has been found to improve self-checking, the control of each step in the decision-making process among the team members, the coordination of information from devices and other team members, and the prioritization of actions and questioning as a group [60]. A recent review on emergency contexts identified differences between individual, TSA and system SA, and emphasized the importance of supporting and sharing relevant information at the right time within the team [69].

According to Endsley [60], skill training, education and structured feedback are essential for improving SA; furthermore, attention-sharing can

be trained and improves individuals' SA. Therefore, it is likely that education in SA might prevent medical errors [10], which is my standpoint in this thesis. Different educational programmes have been developed to enhance SA, mainly in aviation [70- 71], but also in other high-risk organizations such as police [72] and operator training [73]. A six-week scenario-based SA educational programme with a deliberate practice design has been found to result in a higher SA level 1 [74]. Within healthcare, virtual education training programmes in SA have been developed and adapted for operating rooms [75], resulting in communication improvement among students. A qualitative study [76] reported that standardized processes and procedures support SA and might be effective for the detection of patient deterioration and patients at risk. A randomized controlled study [77] that included critical care teams showed a significant improvement in SA level 1 for individuals who had undergone SBT, but not for individuals receiving group lecture-based education. A recent review [78] stated that SBT effectively enhances SA; the authors also suggested that there is a lack of targeted SA intervention programmes.

Although SA has been included as a key concept in large evidence-based educational programmes aiming at improving healthcare team performance and patient safety [55, 59, 79-80], intervention studies in intensive care are lacking. In this thesis, the educational programme that focused on SA included theories, reflection before and after the training session, and training on how to achieve and maintain a high level of SA in the team.

Various techniques have been utilized to measure SA in different contexts. In aviation, observer methods, performance measures, and real-time probe and freeze probe techniques have been used [70-71]. Other instruments measuring SA include the SA rating technique (SART), in which the participants and operator rate SA in terms of attentional demands, attentional resources and understanding [70]. In healthcare education, SA can also be measured using OSCE [81]. In addition, O'Neill [82] recently developed a new taxonomy for resuscitation teams with seven-dimensional framework of behaviours supporting or diminishing SA in healthcare. Still, the situation awareness global assessment technique (SAGAT) is the most commonly used method in healthcare to measure SA [83]. This technique has been used to assess the SA of students handling a patient with deteriorating signs [84], team performance [83], professionals during a trauma simulation [85], obstetrical teams handling critical events [86] and the effects of sleep deprivation on medical professionals [87]. SAGAT has also been shown to correlate with team performance [83] and task performance [88]. This technique involves a "freezing" activity that occurs at set points during the simulation, at which time a questionnaire is distributed to the participants [70, 83]. In order to improve SA, it is important to implement regular team training during stressful and critical situations. In studies I and III, SAGAT is used to measure SA. This thesis aims to evaluate whether a 2-hour education focusing SA improves both team and task performance.

Team performance

For effective team performance, teamwork is necessary. Teamwork is dependent on shared behaviours and cognitions; it is a process that leads towards a goal and that defines how the task is completed [89]. Teams are "a distinguishable set of two or more people who interact, dynamically, interdependently, and adaptively towards a common and valued goal/objective/mission" [90]. Salas [91] points out that teams are stronger than individuals, need supportive organizational conditions and depend on the context; furthermore, even a team full of experts can easily fail if cooperation and communication are underdeveloped. As an organizational psychologist, Salas trained teams in decision-making in complex dynamic environments. To measure team performance in studies I–III, this research used the TEAM scale developed by Cooper [92]. The subscales in the instrument measure leadership, teamwork, task management and overall performance.

Leadership

Team leaders are key components of a team and help the team to construct the team's mental models. Different leadership strategies and communication styles also affect how the team acts during the decision-making process [93-94]. According to a meta-analysis by Ford [95], directive leadership is more effective when the patient is more seriously injured or the team is inexperienced, whereas empowering leadership is more effective for more experienced teams. A team leader needs to communicate her or his role to the other members upon arrival, give clear commands, identify the team members' weaknesses and strengths, allocate the team roles, prepare and plan tasks, and respond to the team members' performance [92].

Teamwork

Challenges for good teamwork in an ICU include the low temporal stability of the teams, rapidly developing technology, severely ill patients, and a complex decision-making process, all of which impede team dynamics and complicate information sharing and shared mental models [96]. In order to avoid medical errors in the ICU, it is necessary to foster a safety culture, which may include proactive thinking about the safety of individuals and teams [97]. It has been suggested that teamwork can be improved by flattening and creating awareness about healthcare hierarchies [79, 98]. In comparison with a high level of cooperation and respect among the team, rudeness can affect procedural and diagnostic performance [99]. Communication and coordination within teams work together to build an accurate and shared mental model of different situations [100]. Shared mental models within a team depend on shared experiences, and on how the team manages to extend information and use cognitive flexibility [101- 102]. One meta-analysis of the effects of team training in healthcare showed that training that involved learning how to transfer essential knowledge, skills, attitudes and abilities was more effective with feedback, and resulted in an improvement in patient outcomes and, eventually, a possible reduction in patient mortality [103]. Finally, a recent study by Kang [104] showed a correlation between perceived

nurse-physician teamwork and the odds of mortality occurring over a 30 day period for surgical patients, based on data from nearly 30,000 nurses from 665 acute hospitals in the United States. After training and education in teamwork skills, team performance behaviours [105] and communication [106] were improved. However, according to my own clinical experiences in the ICU and as a team training instructor, a collaboration that usually works can crackle, for example through the occurrence of contradictions or uncertainty in decision-making, with huge consequences for the patients involved.

Task management

To optimize task management within a team, team members are required to verbalize and prioritize care, have clear objectives and goals, and follow specific guidelines [92]. An observational study that analysed appropriate communication found that shared goals and knowledge, mutual respect, and accurate and timely communication were used by successful interprofessional surgical teams [107]. Interprofessional teamwork involves team members working on different yet interdependent tasks in the ICU, so efficient teamwork and high performance are correlated. Tasks in the ICU may include routine rounds or various acute clinical tasks, depending on the situation [108]. In the anaesthetists´ non-technical skills (ANTS) system, task management consists of planning and preparing, prioritizing, providing and maintaining standards, and identifying and utilizing resources [109].

In this thesis, the TEAM instrument is used to measure team performance in studies I–III. Team performance is a multilevel process that includes the interrelation between teamwork and task performance.

Task performance

Task performance can be oriented to an individual or to the whole team, and may differ in terms of the degree of interaction and coordination with others [89, 110]. Rao [111] and Brunckhorst [112] reported a correlation between specific technical task performance and NTS. Although varied terminology has been used to describe different team factors, in this thesis, task performance involves focusing on the completeness of critical tasks and the standardized management of the patient. This research uses the ABCDE checklist (A=airway, B=breathing, C=circulation, D=disability, E=Exposure) to measure task performance in studies I–III.

Learning and simulation-based (team) training

The design of the studies included in this thesis and project was affected by the Dreyfus and Dreyfus model [113- 114] for skill acquisition, Miller's pyramid and framework [115] for clinical assessment, and Kolb's experimental learning cycle [116]. A Delphi model with international experts formulated a framework for the validation of SBT across surgical specialties supported by the Dreyfus and Dreyfus model for skill acquisition. The framework includes different sets of steps for developing various processes for procedural training and evaluation of cognitive knowledge and psychomotor skills, including the

team components of NTS [117]. Miller's pyramid and framework for assessing clinical skills are also useful when designing training sessions and evaluating SBT [118]. Furthermore, one of the main frameworks in SBT is Kolb's experiential learning theory, which describes changes in an individual's behaviour by actively experimenting to get a concrete experience, reflective observations and abstract conceptualizations [119].

The theory in Dreyfus model states that the learner passes through five steps while developing expertise: novice, advanced beginner, competent, proficient, and expert. The transition involves moving from reliance on rules as a novice, to reliance on intuition and tacit knowledge as an expert and moving from poor quality of decisions to optimal. These steps were used as a framework when developing the upcoming team training sessions (Figure 2).

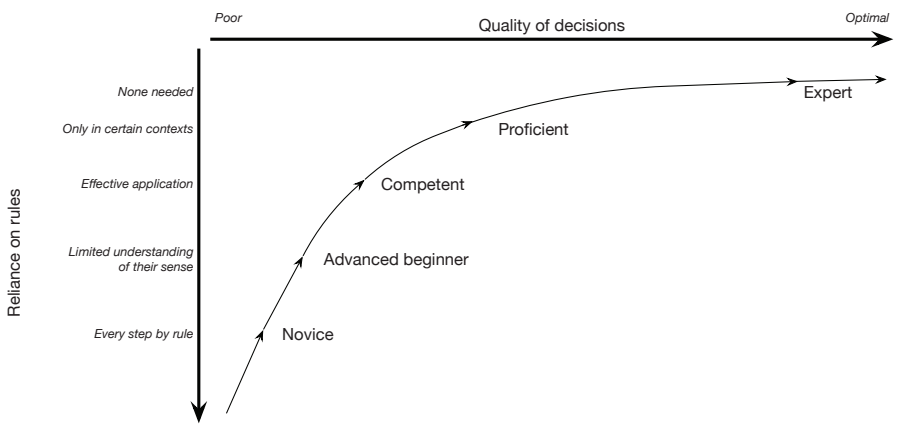

***Figure 2**. Adapted from Dreyfus model of skill acquisition (Dreyfus 1986).*

George Miller [115] published a framework for clinical assessments based on the belief that medical practice is too complex to be evaluated with just one method. Figure 3a shows an adapted version of Miller's model in which knowledge, "Knows", is the foundation. The next level is "Knows how" for competence, then "Shows how" for performance and finally "Does" for action [115].

By stating that "learning is a continuous process grounded in experiences", Kolb established the experiential learning theory in 1976 (Figure 3b). Experiential learning differs from traditional didactic learning and depends on realistic emotional experiences from the participants. The model has four different dimensions: concrete experience – that is, learning through experience; reflective observation – that is, learning from analysing, abstract conceptualization or explanation; and active experimentation – that is, learning through application [116]. Furthermore, for optimal learning, participants must be actively motivated, be guided through the scenario, and be encouraged to reflect both in action and on action [120]. Kolb's theory on experiential learning was utilized in the debriefing and reflection sessions to

increase self-awareness for example by reflection on previous emotional experiences and observation of others.

Miller's pyramid and Kolb's theory of experimental learning were both used in the design of this project and of studies II–III. These theories were used as a starting point for discussions in the research group when developing the educational intervention. Furthermore, schematic drawings showing the main points of the theories were used to deepen the discussions within the intervention groups (Study III). The instructors facilitating the intervention group, were asked to use the existing knowledge from the team and to be aware that participants learn in different ways. By using situations and reflections within the team and by supporting the implementation of new knowledge and the simulation-based team training (SBTT), the teams climbed from "Knows" to "Does". SBTT was used to obtain concrete experience and implement knowledge with reflective questions. The teams also completed a quiz and reflective sessions for conceptualization. Finally, the teams underwent repeated training and the application of new knowledge to strive towards doing/action.

Figure 3a

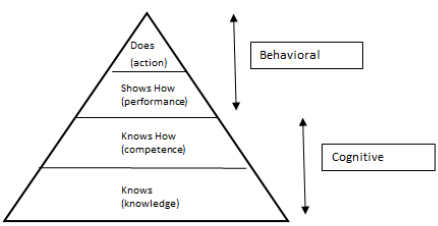

Figure 3a. *The relation between Miller's pyramid of clinical competence [115] and cognitive and behavioural competences. Used with permission from Joong Hiong Sim*

Figure 3b

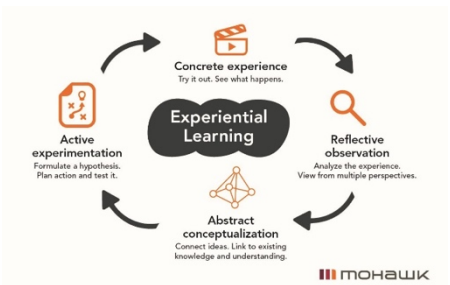

Figure 3b. *Kolb's model of experiental learning[116] . Used with permission from the Centre for Teaching & Learning, Mohawk College.*

Teamwork and patient safety can be improved by using SBTT in the learning process [19]. SBTT has been shown to have a substantial impact on team effectiveness in terms of team, task and mental model improvements [121-122]. One meta-analysis reported that SBT was more effective for task performance and processing information in resuscitation training than non-simulation intervention [123]. SBT can be used during *in situ* medical simulation, which is defined as simulation in a clinical environment using a patient simulator, and in standard simulation, which takes place at various clinical training centres (CTCs) [124]. During SBT, the facilitators/instructors have the opportunity to choose different methods for interacting with the participants, which can result in different outcomes in how the participants act and communicate [125]. Between 2011- 2013, over 5,000 studies on resuscitation training were performed in a simulated environment [123]. A

review from 2019 [126], analysed SBT programmes designed to prevent medication errors, highlight the need for well-designed programs and long term evaluations. SBTT has been suggested to be a central and important part of training for the ICU, since studies in simulation contexts have been reported to enhance team performance and NTS [127].

In addition to SBT, it is essential to foster constructive debriefing and reflection [128- 129]. Thus, the learning process within SBT can be optimized by reflection in practice and thoughtful debriefing [130]. Feedback has been suggested to be essential for learning in a medical context, and must be specific and tailored to learners [131]. In a qualitative study with anaesthesia residents, Sweeney [132] analysed debriefing and reflection after critical events in the clinic and found that debriefing was lacking after many events. That study also stated that after every event that included reconstruction and a reflective session, the participants felt better prepared for next time.

The various learning models and theories used in this project all have *reflection* in common. This focus on reflection was based on the idea that helping professionals to improve their SA and develop a new way of thinking could improve their teamwork. That is, teaching already-experienced individuals might be facilitated by self-reflection, discussions, and reflections with other team members, followed by practice, extended reflection and, finally, more practice. These phases of learning are further described under the heading Intervention.

Rationale

Errors in healthcare cause human suffering and result in major financial strain for both the affected patient and the healthcare system. Some of these errors are preventable and are related to NTS and/or TS. The rapid technical development occurring within intensive care places great demands on healthcare professionals' abilities to ensure safe patient care. In this kind of high-risk organization, healthcare professionals handle massive amounts of information from both hardware and software, and their cognitive abilities are challenged. Through improved collaboration and well-developed teamwork, patient care can be ensured. Research in this area also indicates that mistakes caused by human error could be reduced through training and targeted educational interventions. Unfortunately, research on patient care in life-threatening and time-sensitive situations is somewhat lacking. It is fairly well established that medical errors are related to NTS in some way, including team performance, TS and task performance. However, despite this knowledge, healthcare systems are failing to improve patient care in life-threating situations, probably because evidence on how to improve knowledge – using systematic team training, for example – in comparable situations is lacking. Research in this field should focus on evidence-based, well-designed studies with trustworthy measurements. Furthermore, for application in Sweden, such research should cover a Swedish context. Instruments related to NTS have been developed and used internationally to evaluate simulated training in emergency contexts. However, to the best of my knowledge, no such instruments have been evaluated in Sweden with respect to trustworthiness and feasibility. In addition, some research has found that NTS is related to how teams and team members are aware of the situation in the current context. It is also interesting to consider factors such as age, gender, experiences and education that might influence team and task performance. Furthermore, it is important to survey knowledge on the associations between participants' background characteristics and outcome measures, as this knowledge is valuable for interpreting the results of the intervention evaluation discussed herein. Only a few international studies have reported findings on interventions with the aim of evaluating an educational intervention in SA using team performance – including leadership, teamwork and task management – and task performance as primary outcomes. Although such studies are important, they are difficult to perform. Nevertheless, there is a need to perform both quantitative and qualitative studies evaluating educational programmes in SA in critical care. A more profound competence in how to achieve a higher SA in critical situations might improve team performance and eventually improve patient safety.

Aims of the thesis

This thesis was performed in several steps, following a scientific process: methodological development, a cross-sectional survey, evaluation of an educational programme in SA and, finally, an in-depth interview study was carried out. Thus, the overall aim of this thesis can be divided into four specific aims.

Specific aims

Paper I To test an ABCDE checklist for inter-rater reliability, the TEAM instrument for inter-rater reliability and two SAGAT questionnaires for feasibility and internal consistency.

Paper II To investigate the relationship between team background characteristics and the following outcomes: (1) team performance, including leadership, teamwork and task management; and (2) task performance.

Paper III To evaluate an educational programme on situation awareness for intensive care teams using team and task performance as outcomes.

Paper IV To explore team members' experiences of teamwork within interprofessional teams at an intensive care unit.

Materials and Methods

This thesis uses both quantitative and qualitative methods in order to achieve the aims of the studies. A schematic overview of the studies is presented in Table 1.

Table 1: Overview of the studies

Paper	Participants	Data collection	Outcome variables	Analysis
I	55 individuals / 23 teams, medical students in year 4 at Umeå university.	Video recorded simulations ABCDE TEAM SAGAT Post simulation questionnaire		Statistics: Cronbach´s alpha Normed χ^2 Interclass correlation (ICC)
II	105 individuals / 26 teams from two different hospitals: EN, CCRN, and MD at ICU.	Video recorded simulations Background characteristics ABCDE TEAM	ABCDE TEAM Leadership Team work Task management Total Overall	Statistics: Descriptive Simple and multiple linear regression
III	75 individuals / 20 teams from two different hospitals: EN, CCRN and MD at ICU.	Video recorded simulations Background characteristics ABCDE TEAM SAGAT	ABCDE TEAM Leadership Team work Task management Total Overall SAGAT	Statistics: Generalized estimating equation (GEE)
IV	31 individuals / 9 focus groups: EN, CCRN, and MD at ICU.	Transcribed audio-recorded interviews		Content analysis

EN=Enrolled nurse, CCRN=Critical care nurse, MD=Medical doctor, ICU=Intensive care unit

Setting

Study I

The setting for Study I was a full-scale simulation laboratory in a CTC at a nursing school in the northern part of Sweden. A patient simulator, the Laerdal SimMan (2G), was used as a patient. The simulator was programmed with timed interventions for similar responses to performed actions. The equipment included ordinary medical consumables from a clinical environment.

Study II and III

Study II and III took place *in situ* in the ICU at two hospitals in the northern part of Sweden. Both hospitals have 6–12 ICU beds depending on the time of the year, with a temporarily decreased number of beds during summer and vacations. The patient in Study II and III was a patient simulator, the Laerdal SimMan (3G). As in Study I, the patient simulator was pre-programmed with timed interventions for a similar response to performed actions for the standardization of cases and sessions.

Study IV

Study IV, in which interviews were conducted, was set at one hospital in the northern part of Sweden, in a single room close to the ICU. One of the interviews was performed in the ICU.

Participants

Study I

Participants in an ongoing mandatory SBTT session for medical students in year four were asked to participate in Study I. In all, 55 of 68 students agreed to participate, including females (n=27) and males (n=28); the participants' mean age was 25 (SD=4.5) years. In total, 23 teams with three or four participants in each team were included in the study. Eleven students had previous healthcare education and 20 had earlier experience of taking care of a trauma patient.

Study II and III

Study II requested participation from 215 employees working at two ICUs, 176 of whom were active at that time. A total of 105 agreed to participate, 56 personnel from one hospital and 49 from the other formed a total of 26 teams. Reasons given for dropping out mainly included the high workload at the clinic, difficulties in scheduling and declining to participate. Figure 4 shows the complete description and number of dropouts. The participants consisted of medical doctors (MDs) (n=26), specially educated registered nurses (CCRNs) (n=49) and enrolled nurses (ENs) (n=30). The participating staff members were mostly female (n=79, 75%) versus male (n=26, 25%) and the mean age was 45 (SD=10.1) years.

The participants from Study II were invited to participate in Study III. In total, 75 participants out of the 105 from Study II were included in Study III,

forming 26 teams. After the first training session, the teams were randomized into the control (n=13) or intervention group (n=13). After some participants dropped out, the intervention group consisted of 11 teams and the control group consisted of nine teams (Figure 4), with 39 participants from one hospital and 36 from the other. The participants consisted of mostly females (n=59; 79%). The mean age was 46 in both the control and the intervention group (SD=9.7 vs. SD =9.5). In total, Study III included ENs (n=22), MDs (n=20) and CCRNs (n=33).

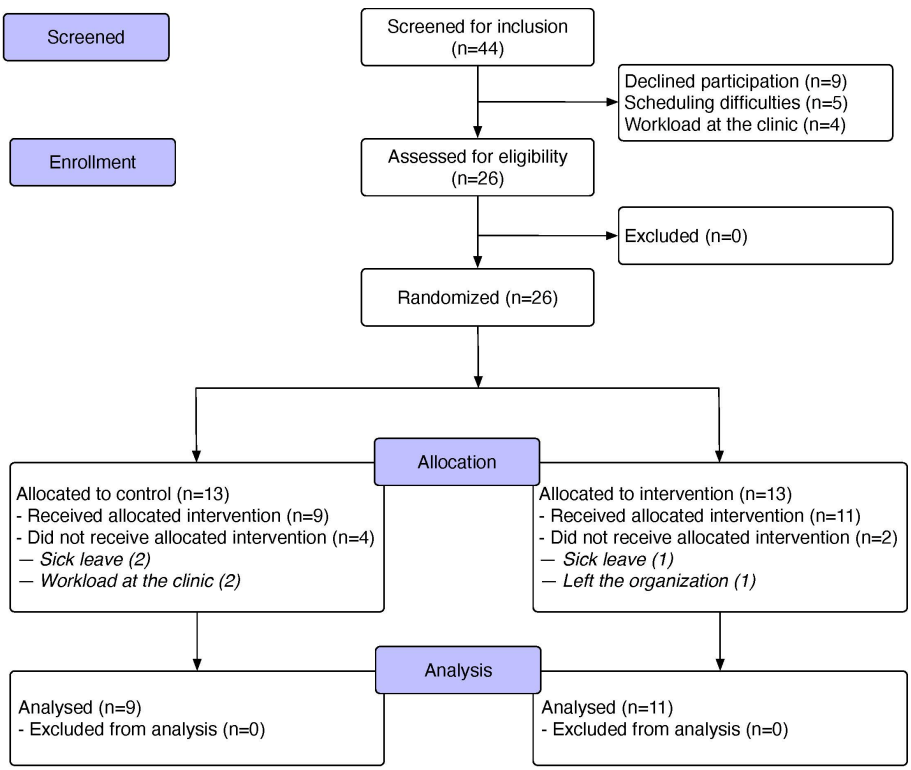

Figure 4. *CONSORT diagram at the team level for Study II and III.*

Study IV

After data-collection for Study III had been completed, the participants from Study II (n=105) were invited to participate in Study IV. Due to difficulty in scheduling the participants from hospital 1 and 18 from hospital 2 declined to participate. Thus, a total of 49 employees were invited to the interviews, out of which 31 employees (ENs=7, MDs=8, CCRNs=16) finally participated. The following interviews were performed for the respective professions: ENs (two focus groups), MDs (three focus groups) and CCRNs (four focus groups). Each focus group consisted of 2–5 individuals. A majority of the participants were females (n=27 out of 31), and the mean age was 45 years (SD=9.7).

Measurements

This thesis uses both validated measurements and study-specific variables. The SAGAT technique was used for SA assessment in Study I and III. Papers I–III were based on data collected from video-recorded sessions. The video recordings were observed and scored using the ABCDE checklist to evaluate task performance and the TEAM instrument to evaluate team performance. To evaluate agreements on the usefulness and feasibility of the SAGAT query, a post-simulation questionnaire (PSQ) was used in Study I.

SAGAT: Situation awareness global assessment technique

Wright was the first to test the SAGAT for validity and reliability in a healthcare context [133]. The SAGAT was recently tested for measuring team SA, and was renamed as the team situation awareness global assessment technique (TSAGAT) in that context [134]. The SAGAT is designed for simulated settings; its main advantages are its direct measurements [70, 83].

In the process of developing the SAGAT questionnaire, goal-directed task analysis (GDTA) was used, as described by Endsley [58, 70]. In GDTA, the major goals and sub-goals for the training session are identified by experts, who also identify the major decisions that need to be made. Various task goals and related decisions are identified. From these, different SA requirements are defined as needed in order to achieve the major goals, as opposed to establishing static information such as rules and guidelines. The questions that are constructed to probe the SA requirements can include multiple-choice and open-ended questions. The questions are then matched against the different SA levels of perception, comprehension and projection [70, 133]. In Study I and III, the scenarios were designed to last for 10–15 minutes; the first freeze occurred 5 minutes into the scenario, unless there was an active task activity or if the team had re-evaluated the situation. The second freeze occurred after 5 more minutes. During the freeze, the patient monitor was switched off and the participants answered the questions while turning away from the patient.

The GDTA and SAGAT queries in this thesis were inspired by a former study [85]. In Study I and III, the GDTA and SAGAT queries were constructed according to the GDTA principles and reviewed by professionals. For example, in order to solve the problem in case 2, it is important to understand and have knowledge about circulation failures related to septic shock. The SAGAT question for level 2 comprehension was: “What is the assessment of C, and on what grounds?” When the feasibility of the SAGAT technique was tested in Study I, the length of the freeze was measured. Every answer in the SAGAT questionnaire was classified as either correct (1) or incorrect (0). In Study I and III, the TSAGAT was calculated as the mean of the individual SAGAT scores.

Post-simulation questionnaire

In Study I, a PSQ inspired by Hogan [85] was used. The PSQ consists of 13 statements to be rated on a four-point scale ranging from *strongly disagree*

(1) to *strongly agree* (4), with the additional option of *I don't know* (0). In this study, the four-point scale was dichotomized into *disagree* (*strongly disagree* and *disagree*) (1) and *agree* (*agree* and *strongly agree*) (2). Five statements concerned the SAGAT technique and eight statements concerned the simulation, the scenario and how the participants experienced the simulator as a patient. Only the five questions related to the SAGAT were used in Study I; if the questions were considered to be relevant to the scenarios and to whether the freeze within the scenarios affected the team training. Participants were also given the opportunity to submit their own comments. The PSQ was initially translated into Swedish by KJ; the translation was then refined based on iterative discussions within our research group. The final version of the PSQ was then verified by a professional translator. Two weeks after the training session, the participants received an email with a link to the PSQ and answered it anonymously.

TEAM instrument

In order to measure team performance in Study I, II and III, the TEAM instrument developed and validated by Cooper et al [92] and Mc Key et al [135] was used. This instrument includes three subscales – leadership, teamwork and task management – as well an overall team performance item. The instrument has been validated with students in simulated environments [88]. In a newly published review of assessment tools in critical situations, the TEAM instrument was highlighted as the most promising tool [136]. In the present research, the English version of the TEAM instrument was used in Study I–III.

The team performance instrument included a total of 11 items distributed on leadership (two items), teamwork (seven items) and task management (two items). Each item was rated on four-level scale (*never/hardly ever*=0, *seldom*=1, *about as often as not*=2, *often*=3, and *always/nearly always*=4). The single item – that is, overall performance – was rated using a continual scale (1–10).

In Study I–III, a mean score was calculated for the respective subscale, as well as for the sum of off all 11 items (total team), resulting in values between 0.00 - 4.00. The item; overall team performance, consists of a single question and is therefore handled as specified the original publication [92].

ABCDE checklist

In 2002, Holcomb [137] developed and tested a scale for trauma teams working with resuscitation training with a simulator as a patient. The assessment tool in that study was modified to fit the specific scenario and included five tasks scored with multiple items (ABCDE evaluation) and eight timed tasks. That tool was adapted as a variation of the validated Advanced Trauma Life Support (ATLS) concept [138] for the assessment of task work, albeit customized to the specific case.

In this thesis, an ABCDE checklist inspired by Holcomb [137] was used. The checklist was designed to evaluate the completeness of critical tasks and

the standardized management of a patient with the following deteriorating signs: airway (one item), breathing (five items), circulation (two items), disability (one item) and exposure (one item). Thus, the checklist included 10 items with five-level scoring options (*not initiated*=0, *performed partly*=1, *performed completely before the end of the simulation*=2, *performed consistently during the whole simulation*=3, and, finally, *not applicable* (NA)). In Study I, the checklist included 10 items; however, the scoring was added with one score option in order to account for the students. Thus, the score was *not initiated*=0, *performed after reminder from the instructor*=1, *partially performed*=2, *performed completely before the end of the simulation*=3, *performed consistently during the whole simulation*=4 and *not applicable* (NA). Moreover, in Study II and III, the checklist was reduced to nine items to score case 1, whereas all 10 items were used to score cases 0 and 2.

Procedures for data collection

Study I

Data were collected from March to October 2016 via audio- and video-recorded team training sessions, questionnaires (SAGAT, PSQ), and observations, followed by scoring of the recorded sessions using the ABCDE checklist and the TEAM instrument. Three high-definition cameras were mounted to record the scenarios. One camera covered the patient monitor, while the other two cameras were set at different angles to record the participants' communication and actions.

One week before the training session, the students were prompted to watch a locally produced movie on the learning platform that introduced the ABCDE concept [138]. Just before the training session began, the participants answered a questionnaire on their earlier education and experience with healthcare. They were also introduced to the simulation laboratory, the equipment and the patient simulator.

During the training session, each group of students trained in four scenarios; the second and third scenarios were included in this study, case A and case B, and their order was randomized. The participants were reminded to maintain discretion about the cases since the groups experienced the same scenarios at different times, participants who had completed a scenario were asked not to discuss it with others who had not yet completed that scenario. In addition to the researcher, one or two teachers and one operator were present in each scenario. The students were told to act as interns, conduct a primary survey and stabilize a critically ill patient for 15 minutes before a senior colleague arrived. Both patients had deteriorating vital signs and suffered from hypovolemic shock (case A) or pneumothorax (case B).

The SAGAT queries were distributed to the participants during the scenario. The SAGAT involves a total of 22 questions separated into two different parts. One week after the team training session, the participants received a mail with a link to the PSQ.

Study II

Data were collected during the spring of 2017 via audio- and video-recorded team training sessions, questionnaires (on the participants' background characteristics), and observations, followed by scoring of the recorded sessions using the ABCDE checklist and the TEAM instrument. This Study II was performed during team training session one (case 0), which was then defined as baseline data collection in the subsequent randomized-control intervention study (Study III; Figure 5).

On the day of the session, the participants answered a questionnaire on their own background characteristics. Next, the participants' goal for the scenario was presented in a pre-session briefing. The goal was: *Use all available resources in the team and use a systematic approach to treat the patient*. The participants were instructed to act as if it were an ordinary day at work. They were given a short introduction to the room and facilities and then taught how to handle the patient simulator. All of the equipment used in the training session was standard at the ICU and was therefore familiar for the participants. To record the scenarios from different angles, two high-definition cameras were mounted. The scenario was designed to last for 15–20 minutes. Before the training session, the level of the scenario had been tested by an independent group of CCRNs and MDs not participating in the study; it was then tested again by the instructors. During the scenario, in addition to the participants, one operator, one instructor, and the researcher were present in the room. The patient was in a life-threatening situation and suffered from several airway problems, such as being intubated to the right bronchi and experiencing a developing pneumothorax. The patient then developed problems with the ventilator and affected circulation. After the scenario, the participants had a debriefing session to discuss their goal for the session. The session took one hour in total. After the session, the participants were reminded to be discrete about the cases.

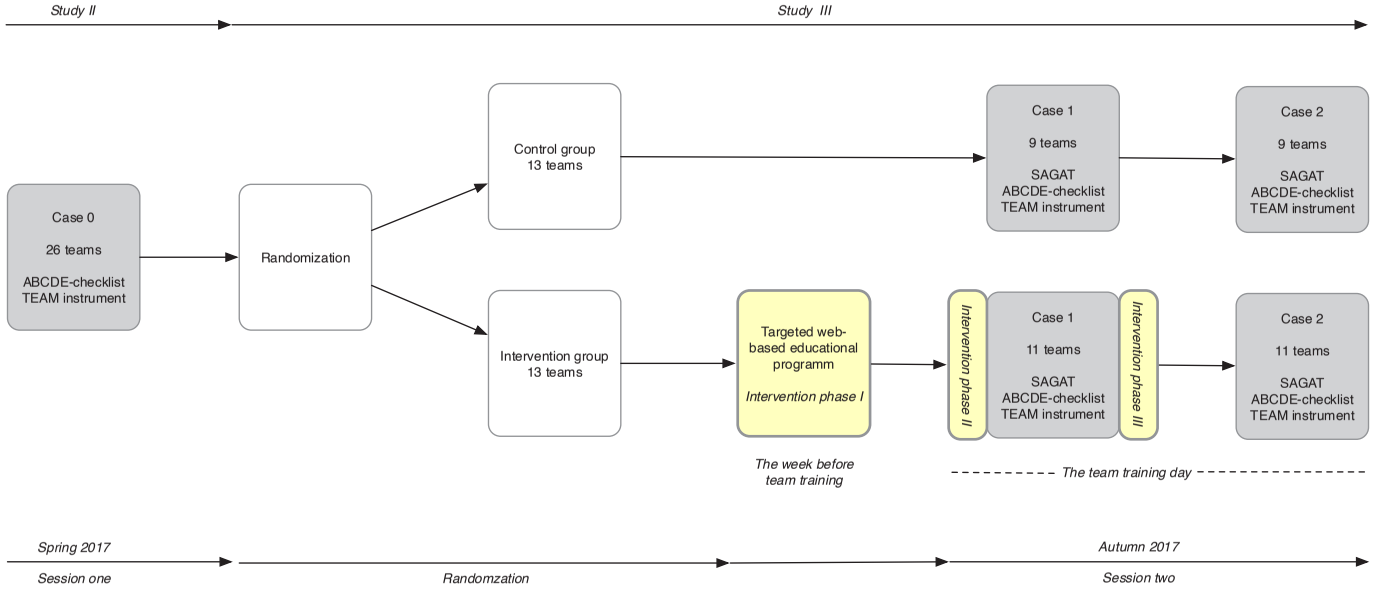

Figure 5. *Flow chart depicting the activities in study II and III. Simulation sessions are shown as gray boxes, randomization is shown as white boxes, and interventions are shown as yellow boxes.*

Study III

The data used in Study III were collected during the spring of 2017 (case 0) and the autumn of 2017 (cases 1 and 2; Figure 5) via audio- and video-recorded team training sessions, the SAGAT questionnaire, observations, followed by scoring of the recorded sessions using the ABCDE checklist and the TEAM instrument. Before data collection for cases 1 and 2 took place, the team training instructors and the participants were randomized into either the control or the intervention group by drawing lots. A description of the intervention is provided below.

Before case 1 began, participants were presented with the goal for the training in a pre-session briefing. The goal for case 1 was: *Stabilize a patient with respiratory failure and optimize the communication within the team*. Case 2 had the same goal as case 0: *Use all available resources in the team and use a systematic approach to treat the patient*. The cases were designed to last for 15 minutes, and the participants were instructed to act as if it were an ordinary day at work. Two cameras were mounted to record the participants' actions and communication, and to record the monitors.

Also, in this part the scenarios and SAGAT questions were tested to to ensure that they were at an appropriate level of difficulty for the control and intervention groups by MDs and CCRNs who were not involved in the study. The instructors were also introduced to the cases, the planned events and the handlers. A total of 12 instructors were involved in the training sessions, six from each hospital, three of which were randomized to each of the control group or the intervention group. The goals for the team training session and the cases were the same for the control and the intervention group. As before, the participants were reminded to be discrete about the cases.

Both cases (case 1 and 2) began with a standardized brief handover report from one of the instructors. At the start of the scenario, one operator, one instructor, and one researcher were present in the room at the ICU along with the participants. Next, the patient arrived at the ICU together with the researcher or an instructor, who gave the short handover. In case 1, the patient was awake and suffering from chronic obstructive pulmonary disease with exacerbation. In case 2, the patient was almost unconscious and in septic shock.

The SAGAT questions were distributed to the participants while the scenario was temporarily halted, or "frozen". Thirteen questions were handed out to the participants in case 1; after the questions had been answered, the scenario started up again. In case 2, the questions were divided into two sets of questions that were answered during two "freezes".

Intervention

The intervention study was complex, both in designing the intervention, in performing the data collection, and in the evaluation. There were several interacting components both in the intervention, the participating organizations, and in the assessments. According to Craig et al, the best practice in these situations is to develop the interventions systematically and

then to test them in a phased approach [139]. The planning, scheduling and organization of the intervention began in autumn of 2016. The intervention consisted of an educational programme in SA.

After team training session one and before the educational programme started, the instructors who had been randomly assigned to groups of participants in the intervention, were given specific instructions. The instructors received a day of instructor training that covered SA and efficient team coordination. The instructors also took part in the web-based educational programme that was later given to the participants. There was also a discussion on how to use the knowledge/or implement learning from the questions and quiz during the reflective sessions.

Intervention group

The intervention was developed by using the following theories, concepts and models of SA, team performance and learning: (1) Endsley's model of SA [58]; (2) Salas' [50, 89] concepts of teams and teamwork knowledge; and (3) the learning theories described by Dreyfus and Dreyfus [114], Kolb [140] and Millers [115].

The web educational programme and the instructors discussed different levels of SA based on Ensley's theory [58] and how to achieve and maintain a high level of SA. Obstacles and potential remedies to obtaining SA were examined, including how to handle different external and internal stressors. Salas' theory was also applied in order to provide the participants with an understanding of the meaning of "team" and "teamwork". The web programme introduced the complexity of team performance, the challenges faced by interprofessional teams and how to optimize team and task performance; these topics were then further discussed by the group, facilitated by the instructors.

One goal presented during the intervention was to discuss teamwork as a process that must be trained, practiced and reflected upon. The reflection sessions, which took place before and after the SBT, were intended to create a milieu that promoted awareness, self-reflection and constant development and progression, driven by the participants and facilitated by the instructors. During the web part of the educational programme, questions and quizzes were implemented to achieve reflective pauses and cogitation; the participants' different thoughts were later requested during the training session.

The educational programme contained three phases: web education (*phase I*) and two reflective sessions (*phase II* and *III*; see the flow chart in Figure 5). Parts of the intervention were used with permission from The Royal College of Physicians and Surgeons of Canada: *Situational Awareness and Patient Safety*, which was founded by the Canadian Medical Protective Association [59]. Figure 6 and 7 are examples from the educational intervention that were used during the reflection sessions.

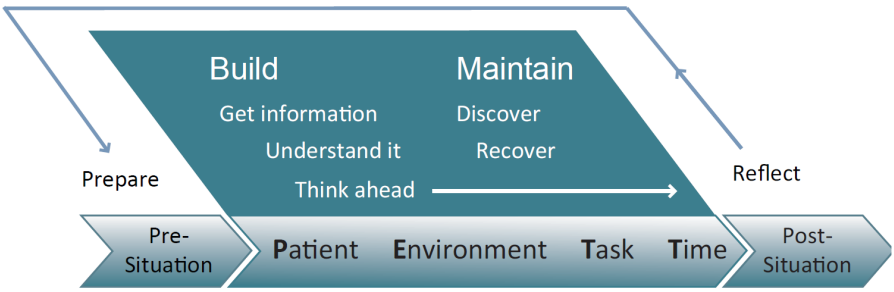

Figure 6. *Example from the educational intervention showing a model for the creation of SA. (Used with permission from The Royal College of Physicians and Surgeons of Canada.)*

Phase I

A web-based educational session containing theoretical blocks, reflective questions and quizzes was mandatory for the participants in the intervention. The theoretical parts were about learning, work environment, interprofessional education, patient safety, non-technical skills and (mostly) situation awareness. The web educational session was designed to be completed in 1 hour, including pauses for reflection and quizzes. The topics were: (1) human factors and their significance for clinical practice [79, 141-142]; (2) theories on optimizing the abilities of team members and identifying their own strengths and weaknesses [37, 143-144]; 3) descriptions for understanding SA [58]; and (4) theories on how to use SA in clinical practice [59, 61]. The participants in the intervention groups were requested to participate in the web-based educational session during the week before the simulation training. The participants had individual logins to allow reminders to take part in the education.

Phase II

Team training session two started with a 1-hour reflective discussion based on the web educational session with a focus on SA, facilitators and obstacles for SA, and learning from reflection and experience. Positive and negative arousal and stress in relation to performance and SA were also discussed.

Phase III

Phase III consisted of a reflection session [130] directly after case one, together with the instructors. The core/overall theme in the web-based educational session was SA; thus, the reflection session focused on how to turn the theory of SA into practical skills. A model was used during the reflection in phase II (Figure 7). The discussion began with an introductory question: "What is important for the middle [part of the model] and how do you share it with the other team members?"

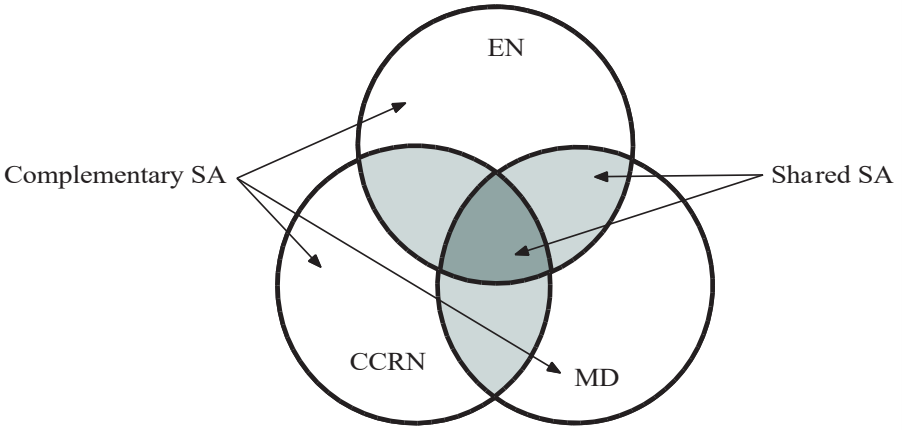

Figure 7*. Complementary and shared SA requirements. Model used for reflection during debriefing for the intervention group. (Model inspired by Nemeth, C. P. 2016 [1]).*

Control group

The control group did not participate in the web educational or reflection session before the training session. A document with a specific timetable and a short presentation on the SAGAT technique were distributed to the instructors for the control group. After each case, the control group had debriefing sessions that included the same didactic as those in the intervention groups – that is, facilitated discussions based on the different phases of reflection: reaction, analysis, summary and application [130]. To reduce spillover effects, the control groups had their team training scheduled before that of the intervention groups.

Study IV

About 12 months after the data in Study II had been collected, focus group interviews were held during spring and autumn 2018. All participants from Study II and III were invited to participate. The focus groups were divided based on professional affiliation. Thus, the aim was to invite the participants into groups divided by professions to talk about experiences of teamwork while being free to discuss different views [145]. An interview guide was set up, and the participants were told beforehand about the aim of the study. After a short introduction, the use of a broad open-ended question encouraged the participants to talk about their experiences [146] of teamwork. The interviews lasted for 39–66 minutes were audio recorded and transcribed verbatim.

Data analyses

All quantitative data (Study I–III) were analysed using IBM SPSS Statistics for Windows, version 24 (Study I–II) and version 25 (Study III) (IBM, Chicago, IL).

Calculation of power

The TEAM instrument was used for the calculation of statistical power for the studies. Since the queries in the SAGAT technique differed from case to case, power analysis was not possible. No previous study had been performed with the ABCDE checklist, so that checklist could not be used for power calculation. Therefore, the statistical power calculations to determine the number of participants needed for the studies in this thesis were based on the TEAM instrument descriptive measures published by Cooper [92]. In Study I, in order to detect a large effect size (Cohen's D of 0.9), 16 participants were needed, as determined with G*Power [147] using a paired samples t-test (80% power, at the 0.05 significance level). In Study II and III, using the mean TEAM total of 2.49 and SD of 0.91 and aiming to detect an increase in the mean of 1.0 with a power of 80% at the 0.05 significance level, 22 teams in total would be needed.

Study I

In order to analyse inter-rater reliability, four raters viewed the video-recorded simulations for the assessment of the ABCDE checklist and the TEAM instrument. Each recorded scenario was viewed individually several times. Before the assessment started, two meetings were set up at which the raters discussed the interpretations of the anchors in the ABCDE checklist and the TEAM instrument. The assessments of team performance and task performance were focused on the whole team and were performed independently. To calculate agreement between the raters, inter-rater reliability and intraclass correlation (ICC) using a two-way random effect model (ICC (2,1) type absolute) [148-149] were used. Both single and average measures were presented.

To analyse the feasibility of the SAGAT questionnaires, the questions were reviewed by three professionals. The answers given by the participants in the SAGAT instrument were classified as incorrect (0) or correct (1) by two of the authors (KJ, MHu) in the manuscript. To calculate the internal consistency of both SAGAT and TSAGAT, Cronbach's alpha [149] and a normed X2 [150] were used.

The PSQ was used to investigate the feasibility of the SAGAT query. The PSQ included five questions about the relevance of the questions in the SAGAT and whether the freezing affected the performance. The results from the PSQ were presented using descriptive statistics.

Study II and III

In Study II and III, two of the authors (MHu, MH) scored the scenarios by using the recorded videos from team training sessions one and two, (case 0, 1,

2). Initially before scoring the TEAM instrument and the ABCDE checklist, the raters discussed the interpretations of the descriptions for scoring the items. A description of the TEAM tool was used for applicable prompts and as a support for the anchors [151]. Each scenario was viewed individually several times; thereafter, the raters performed the scoring independently.

The first step in the statistical analyses was to test the normality of the dependent variables by histograms and skewness. Thereafter, further statistical analyses were performed, as discussed in the following paragraphs.

Specific Study II

Initially, as a quality assurance, the agreement between the raters was calculated using an intraclass correlation (ICC) [148]. To analyse and explore the relationship between the independent and dependent variables, simple and multiple linear regression analyses were used. The dependent variables used were mean scores based on the respective subscale in the TEAM instrument and the ABCDE checklist. The independent variables were the mean value of the background characteristics for the respective team. In order to test for multicollinearity, a correlation matrix was calculated. Next, simple linear regression analyses were performed for each independent variable in relation to the outcome (dependent variable). In this step, a *p*-value lower than 0.2 was used to select independent variables for further analyses. In the final analyses, multiple linear regression analyses were performed for each dependent variable. Backward elimination procedures were used until only variables significant at the 0.05 level remained in the models. Out of the results from the simple regression analyses and due to the sample size, no more than five independent variables were analysed in the first multiple model for each dependent variable.

Specific Study III

Initially, in the analyses of Study III, the answers given by the participants in the SAGAT instrument were classified as either incorrect (0) or correct (1). This classification was performed by two of the authors (KJ, Mhu).

To calculate and explore the effect of the intervention, a generalized estimating equation (GEE) model [152] was used. A mean individual score was calculated for TSAGAT, the ABCDE checklist and the TEAM instrument, respectively, and these were used as dependent variables. Assuming a scale linear model with an independent correlation matrix, the GEE model accounted for testing between the intervention and control group, time (case 0, case 1, and case 2) and changes over time between the intervention and control groups. We used the GEE models to analyse changes from case 0 to case 2, and from case 1 to case 2, respectively.

For analyses of the differences in background characteristics between the intervention and control group, independent sample t-tests or the Chi-square test were used.

Study IV

To further explore the participants' experience of teamwork in interprofessional teams in the ICU, focus group interviews were performed. A qualitative content analysis, as described by Graneheim and co-workers, was performed [153- 154]. The transcribed interviews were read several times to gain a sense of the whole. The software tool MAXQDA 2018 [155] was used for sorting and preparing the texts. Initially, meaning units corresponding to the aim of the study were identified. In the next step, these meaning units were condensed. Thereafter, the units were coded based on the content in the meaning units. Next, the codes were organized into subcategories based on similarities and differences. Subcategories with similar content were placed in the same category. Finally, a theme emerged based on the content of the categories and is a metaphor for the participants' experiences of teamwork in the ICU. The initial coding was conducted by the first and last authors (KJ, MHa). All authors were involved in the analysis and discussed the results until consensus was reached.

Ethical considerations

The studies in this thesis were approved by the Ethical Review Board of Northern Sweden, April 7th, 2016, decision No. 2016-54-31M. All studies followed the principles of World Medical Association Declaration of Helsinki [156], and the data in the studies were handled with confidentiality.

For Study I, contact was first initiated with the students' course coordinator and the chair of the department to obtain approval for the project in order to apply for an ethical review. For Study II–IV, approval was obtained from the chairs of the departments before applying for an ethical review.

The team training sessions in Study I–III were mandatory, but participation in the studies was voluntary and the participants in the training sessions could decline at any time to participate in the study. A team was only included in the study if all of the participants in that team agreed to participate.

Study III, the randomized controlled study was not "trial registered", as it did not have any health outcomes after a healthcare intervention on human participants.

Information about the respective studies was presented in both written and verbal form to all the students in Study I and to the acute care personnel in Study II–IV. Participants signed informed consent forms individually immediately before the start of the training session in Study I and II. The informed consent form for Study II included information and consent for Study III and IV as well.

A potential ethical issue was that the participants might be exposed to peer pressure, since a team would be excluded from the study if one team member declined participation. This was discussed in the research group and with the instructors to minimize the risk.

Results

This chapter presents the main results of each study: "Measurements of situation awareness, team and task performance" (Study I), "Factors influencing team and task performance" (Study II), "Evaluation of an educational programme in situation awareness" (Study III) and "Experiences of teamwork in interprofessional teams in an ICU" (Study IV).

Measurements of situation awareness, team and task performance (Study I)

In Study I, we tested the feasibility of the SAGAT questionnaire and the internal consistency of the ABCDE checklist and the TEAM instrument.

The results of this study show that SAGAT was a useful technique with questions that were relevant to the cases. The majority of the participants (72%) considered that the "freezing" of the scenario did not have a negative impact on their concentration or on the performance of the scenario. The SAGAT questionnaires were analysed for cases A and B to determine the respective level in SAGAT (levels 1, 2, 3) and the total SAGAT. The analyses indicated good [150] internal consistency; at the individual level, Cronbach's alpha was 0.80 for case A versus 0.62 for case B. The corresponding values for the team analyses (TSAGAT) were 0.83 (case A) versus 0.76 (case B) (Table 2). The normed χ^2 was 1.72 versus 1.62, indicating a good fit and a sufficiently good homogeneity for the questions included in the query. Cronbach's alpha was low for levels 1 and 2 but higher for level 3, at both the individual level and the team level.

Table 2. Cronbach's alpha in cases A and B for SAGAT and TSAGAT.

	SAGAT Case A/B n=39/36	TSAGAT Case A/B n=12/11
Level 1 – perception	0.060/0.246	0.372/0.420
Level 2 – comprehension	0.321/0.332	-0.018/0.332
Level 3 – projection	0.891/0.659	0.891/0.786
Total (Level 1–3)	0.800/0.620	0.827/0.759

The analyses of inter-rater reliability for the ABCDE checklist and the TEAM instrument indicated a sufficiently good stability [148] of the respective instruments. The ICC result was 0.55 (single measures) and 0.83 (average measures) for the ABCDE checklist, and 0.54 (single measures) and 0.83 (average measures) for the TEAM instrument.

In summary, the results in Study I indicated that the SAGAT technique, the ABCDE checklist and the TEAM instrument are useful for measuring team performance, task performance and SA during SBTT with critical care cases in a Swedish setting.

Factors influencing team and task performance (Study II)

In Study II, the relationship between ICU team background characteristics and team performance (leadership, teamwork, task management) as well as task performance were analysed.

At the individual level, the mean age for the participants was 45.1 (SD=10.1) years and the mean number of years of prior work experience was 16.6 (SD=10.7) years. All nurses and a majority (19 out of 26) of the physicians were specialists in critical care. Half of the participants had former experience of CRM training, but only a fourth had former education in leadership (24%) or communication (22%) in acute situations. The results of the univariate analyses at the team level are presented in Table 3. The multiple linear regression showed that age was significantly related to teamwork, task management, team overall, total team, and task performance (Table 3). Moreover, prior education in communication was significantly associated with poor leadership, and prior team training without video was significantly associated with high task management.

Independent variables that were excluded (p-value above 0.2) from the univariate analyses were prior work experience, prior courses, prior experience in CRM, and perception of daily frequency of teamwork.

In summary, this study showed that higher age was associated with aspects of better team performance such as teamwork, task management, team overall and total team. Prior team training without video was associated with better task performance. It is notable that prior education in communication was associated with poor leadership.

Table 3. Results from simple and multiple regression analyses presented with β, p-value and R2. Dependent variables: team performance (TEAM instrument: leadership, teamwork, task management, team overall, and team total) and task performance (ABCDE checklist) for the total number of teams (n=26).

Variable tested	**Leadership** β and *p*-value simple		**Teamwork** β and *p*-value simple		**Task management** β and *p*-value simple		**Team overall** β and *p*-value simple		**Team total** β and *p*-value simple		**ABCDE checklist** β and *p*-value simple		**Leadership** β and *p*-value multiple R^2=0.21		**Teamwork** β and *p*-value multiple R^2=0.17		**Task management** β and *p*-value multiple R^2=0.15		**Team overall** β and *p*-value multiple R^2=0.20		**Team total** β and *p*-value multiple R^2=0.17		**ABCDE checklist** β and *p*-value multiple R^2=0.33	
Age	.028	0.22	**.036**	**0.04**	**.040**	**0.05**	**.085**	**0.02**	**0.35**	**0.04**	**.019**	**0.03**			**.036**	**0.04**	**.040**	**0.05**	**.085**	**0.02**	**0.47**	**0.04**	**.017**	**0.04**
Gender	-.234	0.62	-.330	0.52	-.231	0.70	-.987	0.38	-.311	0.54	**-.367**	**0.14**												
Hospital	**-.426**	**0.05**	-.027	0.88	-.024	0.91	.208	0.59	-.099	0.57	.053	0.54												
Specialist diploma	.140	0.64	.187	0.42	**.392**	**0.14**	**2.085**	**0.15**	.216	0.35	.140	0.22												
Physician at specialist level	**-.067**	**0.08**	-.012	0.70	-.040	0.27	.376	0.38	-.027	0.38	**-.021**	**0.17**												
Prior experience with debriefing, video	**-.623**	**0.16**	.175	0.62	.036	0.93	.229	0.51	.005	0.99	.209	0.23												
Prior edu* leadership	-.374	0.52	**-.848**	**0.05**	**-.849**	**0.10**	**-1.901**	**0.05**	**-.762**	**0.08**	-.258	0.25												
Prior edu* communication	**-1.299**	**0.02**	**-.700**	**0.11**	**-.728**	**0.17**	**-1.895**	**0.05**	**-.814**	**0.06**	-.268	0.23	**-1.299**	**0.02**										
Prior TT with video**	**-.507**	**0.19**	.167	0.59	.041	0.91	.515	0.48	.021	0.95	.156	0.31												
Prior TT without video**	-.159	0.75	.163	0.67	.377	0.40	.929	0.27	.143	0.71	**.400**	**0.03**											**.349**	**0.04**
Perception of positive value of TT**	-.117	0.88	**.949**	**0.12**	.514	0.49	1.482	0.28	.676	0.27	.171	0.58												
Perception of good quality of TW***	-.224	0.82	.214	0.78	**1.261**	**0.15**	1.897	0.25	.325	0.67	**.528**	**0.16**												

*Education, **Team training, ***Teamwork; the table shows the unstandardized beta coefficient

All variables with a p-value <0.2 in the simple linear regression models are bolded as well as remaining variables after the stepwise backward elimination procedure in the multiple linear regression models (p<0.05).

Evaluation of an educational programme in situation awareness (Study III)

In Study III, an educational programme focusing on SA for intensive care teams was evaluated in a randomized controlled intervention study using team performance, task performance and team SA as outcomes.

There were no significant differences in background characteristics such as age, experience, education and training between the participants in the control group (n=9) and those in the intervention group (n=11). However, the intervention group had a higher proportion of participants that had taken a course in structured management of severely ill patients compared with the control group (mean= 0.76 (SD 0.18) versus 0.55 (SD 0.26), p=0.041).

The generalized estimating equation (GEE model) testing of the differences and changes over time between the intervention and the control group demonstrated significant improvements in respect to the TEAM subscales *leadership* and *task management* as well as the *total* score from case 1 to case 2 (Table 4).

Table 4. Estimated mean score and changes between the intervention and control group on outcomes for case 0 *vs.* case 2, and for case 1 *vs.* case 2, respectively.

	Intervention group mean (SE)			**Control group mean (SE)**			**Differences in mean change between intervention and control**	
	case 0 (n=13)	case 1 (n=11)	case 2 (n=11)	case 0 (n=13)	case 1 (n=9)	case 2 (n=9)	case 0 vs case 2	case 1 vs case 2
TEAM instrument								
Leadership (score 0.00-4.00) [a]	2.77 (.11)	2.67 (.11)	3.17 (.10)	2.48 (.17)	2.50 (.12)	2.59 (.11)	mean change = .30 SE = 0.20 p =.149	mean change=.42 SE = 0.14 **p = .003**
Task management (score 0.00-4.00) [a]	2.73 (.13)	2.50 (.11)	3.12 (.07)	2.71 (.15)	2.60 (.08)	2.85 (.14)	mean change = .24 SE = .17 p = .157	mean change =.36 SE = .15 **p=.018**
Total (score 0.00-4.00) [a]	2.64 (.09)	2.50 (.08)	2.91 (.08)	2.53 (.14)	2.47 (.08)	2.70 (.10)	mean change =.10 SE = .13 p = .434	mean change = .18 SE = .08 **p = .030**

[a] higher score indicates a higher degree of performance
[b] higher score indicates a higher SA

There were no significant differences between the intervention and control group in the TSAGAT, ABCDE checklist, or TEAM subscales, teamwork and overall.

In summary, this study stresses that education in SA is important for intensive care teams in order to improve both team and task performance.

Experiences of teamwork in interprofessional teams at an ICU (Study IV)

In Study IV, the emerging theme of *balancing between knowledge and behaviour in teamwork* highlighted the difficulties of working in interprofessional teams and illustrate the participants' experience of teamwork with aspects that facilitated or acted as barriers (Table 5). This metaphor not only emphasizes the importance of skilled and knowledgeable participants in the ICU team, but also highlights the effect of the team members' supportive or disruptive behaviour on teamwork. Related categories and corresponding subcategories revealed differing aspects of team composition, work environment and distribution of tasks that could act as facilitators or barriers in the interprofessional teams' teamwork.

Table 5. Theme, categories and subcategories of participants' experiences of aspects that facilitate or acts as barriers to teamwork.

Sub-categories	Categories	Theme
Being surrounded by expert knowledge and developing as a team	Having potential for excellence while dealing with members who do not act as team players	***Balancing between knowledge and behaviour in teamwork***
Conflicts occurring between team members, that jeopardize teamwork		
Receiving and giving support and mutual respect	Creating a safe atmosphere while working in an unknown environment and struggling to maintain one's positions	
Coping in a familiar and unfamiliar environment		
Gaining an overview of the situation and its development	Being in a workflow without becoming overwhelmed	
Being overloaded with multiple tasks		

Having potential for excellence while dealing with members who do not act as team players: When they had the opportunity to elaborate together as a team during team training, the team members described their experience as facilitating. Having expert knowledge (including tacit knowledge) ensured the teams competence and facilitated the teamwork. The participants viewed working with people who supplemented their own knowledge and skills as a positive experience. On the other hand, conflicts that occurred within the team could jeopardize teamwork. In situations with conflicts between team members, frustration, resignation and anger were created. The participants described having a common goal for the daily work that was necessary for

having a sense of being a team. If the common goal for a patient was not followed as agreed upon, a feeling of being sidestepped could arise.

Creating a safe atmosphere while working in an unknown environment and struggling to maintain one's positions: The team members described the importance of receiving and giving support and mutual respect in the team. Creating an environment built on supportive behaviour, respect and trust made it easier to speak up and have a different opinion. In stressful situations, assistance with tasks was appreciated; however, it was important that the helping person did not just take over the task and assignments. In contrast, being in an unfamiliar environment and working with unknown personnel were experienced as a barrier for teamwork. Disparities in communication and task performance made it more difficult to collaborate. Some participants described ICU as "their nest" and stated that entering another ward, such as the emergency ward, in a chaotic situation such as during resuscitation was experienced as challenging. Not knowing who to talk to and not knowing one's role or position in the team were experienced as a barrier for teamwork. These situations could also occur in the ICU during a struggle for leadership position between MDs.

Being in a workflow without becoming overwhelmed: Gaining an overview of the situation and its development and experiencing a sense of flow at work were perceived as satisfying, contagious in a positive way. Although re-evaluating a situation was described as helpful, it needed to be performed in a timely manner. Preparedness and having a plan were described as important and essential for fluent teamwork. ENs concentrated on specific keywords that helped them to prepare for the next step. When team members had prior experience of critical tasks and were able to shift positions, the team became more effective. However, the complexity in critical situations was described as a barrier for teamwork when the team members felt overloaded with multiple tasks. In addition, timely communication with relevant context was not always achieved by the team members. The professions were faced with various disturbances; The MDs described situations when frequent interruptions occurred during critical tasks, which were experienced as frustrating. The CCRNs and ENs also considered it important to have prescriptions and requests delivered at the right pace in order to ensure that everything was done.

In summary, this study highlights the importance of knowledgeable and skilled participants in the ICU team; it also depicts the effect of behaviour – both supportive and disruptive – on teamwork.

Discussion

This thesis has several important standpoints. The main focus of this research was to investigate the effect of an educational programme in SA developed for ICU teams using team and task performance as evaluation outcomes. However, before implementing the educational programme, the instruments used in this thesis were tested for feasibility and reliability. After that, the relationship between team members' background characteristics and team and task performance was investigated. The findings in this thesis add new knowledge and give strength to previous research in the fields of SA, team performance and task performance in ICU teams. These new findings are elaborated below.

The main findings from Study III and IV will be discussed first, followed by a discussion of the results from Study II. The discussion then moves beyond the scope of the four studies included in this thesis and focuses on the most important findings. Since Study I focused on testing three instruments for trustworthiness, its findings will be discussed in the section titled methodological considerations.

Does education in SA for intensive care teams influence team and task performance?

The SA-focused educational programme used in Study III was found to improve team performance, including the subscales of leadership and task management. Previous research on SA in aviation and in the control rooms of industrial complexes has shown that systematic training in SA improves team performance [71]. However, in healthcare there is a lack of studies on educational programs focusing SA [78].

In healthcare, SA is often trained as a part of NTS bundles such as CRM [79] and TeamSTEPPS [55]. These bundles have been shown to improve team performance [54, 56, 157]. High NTS skills have also been associated with high technical skills in the healthcare context [158]. This finding is further supported by Sollid [159], who reported that training in a combination of technical skills and NTS has the best outcome for patient safety.

The educational intervention in Study III focused on SA, but in the context of other NTS. Former NTS research has focused more on social NTS such as communication, teamwork and leadership, as compared with cognitive NTS such as SA and decision-making [29, 160]. A recent review from Glavin and Flin [161] emphasized that SA is a relevant key competency due to increasing complexity in healthcare. In another review, Jones et al. [35] focused on team performance and stated that poor communication leads to a loss of SA, which then causes failures in decision-making. Thus, educational programmes that focus on different parts of NTS might need to be evaluated in parallel in order to decide upon an optimal design and focus for improving team performance.

As pointed out in the background, several reviews indicate that SA is of importance for team performance, but specific studies, especially randomized controlled trials, are lacking. SA as a part of cognitive NTS is difficult to

separate from social NTS in an educational program but teaching sessions and learning activities may be directed to address the cognitive skills. The educational intervention was designed to deepen the participant's knowledge about the different levels of SA, their hierarchal dependencies, what promotes and hinders obtaining SA and how a team together may enhance the collective SA. As suggested by Brady [76], an education in how to enhance SA might contribute to earlier identification and mitigation of errors and recognition of deteriorations before they escalate.

The two-hour additional education for the intervention group that was tested in Study III did increase team performance. By focusing on SA in the education both leadership and task management was improved. Leadership according to the TEAM instrument is how the leader managed to let the team know what was expected of them and how the leader maintained a global perspective. Being able to maintain a global perspective and instruct the team during a stressful situation was thus enhanced by the education. Task management is a composite of how the team prioritized tasks and how the team followed approved standards and guidelines [92]. For being able to prioritize and to follow guidelines it would appear necessary to have a good perception of what is going on (SA level 1) and to comprehend what is happening (SA level 2) [14].

In summary, the present study suggests that systematic education focusing on SA might be beneficial for team performance. However, an extensive literature search did not reveal other studies that have measured the effect of an SA-focused educational intervention on team performance in a healthcare context. Therefore, there is a need to further evaluate whether educational programmes aiming to improve SA do indeed improve teamwork.

How do team members experience teamwork within interprofessional teams at an ICU?

In this thesis, an overall theme, *Balancing between knowledge and behaviour in teamwork*, emerged from the categories having potential for excellence while dealing with members not acting as a team player; creating a safe atmosphere while working in an unknown environment and struggling to maintain one's position; and, finally, being in a workflow without becoming overwhelmed (Study IV).

The theme highlights the importance of knowledge in an ICU team, while simultaneously emphasizing how team members are affected by their colleagues' behaviour during on-going teamwork. Being surrounded with expertise within the team was experienced as a facilitating aspect for teamwork. The participants expressed pride and felt confident when they were working in a team with "the right" colleagues who knew what would be coming up next. This finding is in line with earlier research [162-164] and Hjortdahl et al [165] found that leaders with knowledge and technical competence instilled confidence into their trauma teams. According to the participants, being surrounded with experts (from all three professions) in the team had a positive impact on the team performance.

The result showed that unpretentious behaviour and striving for respect facilitated teamwork and created a safe atmosphere for the team. Receiving support, mutual respect and high-quality leadership has been described as producing a sense of psychological safety [166], which could apply to our findings as well. Salas [91, 166] has also pointed out similar facilitators. He showed that interdependent work, including back up behaviour, trust, learning and mitigation of errors, was essential for teamwork. Similarly, the interviewees in the present research mentioned back up behaviour, along with being understanding and willing to allow colleagues to be novices while more experienced colleagues waited in the background ready to provide support when needed. Klein and co-workers [167] found that shifts occurred in leadership when senior doctors actively supported their junior colleagues and took on a more active and influential role when the situation became more critical. Here, it should be noted that, in order to be able to provide this kind of support to junior colleagues, senior colleagues must have access to knowledge and updated information.

Continual discovery and continually updated information are needed to maintain a high SA [59-60]. In Study IV, the participants experienced satisfaction from being in a workflow without becoming overwhelmed. Even in dramatic, chaotic situations, collaboration within the team could be excellent. When the physician was occupied with tasks, another team member would maintain an overview of the situation and would update the team continuously. However, there is a thin line between being in a state of flow and becoming overloaded with tasks. Previous research has stated that in highly technical environment such as the ICU it is common with high workload of complex and critical tasks [168]; and this type of environments will affect individuals' working memory, which has been reported as a hindrance to SA [14]. This research aligns with the findings from our interviews: the interviewees described emotions related to being overwhelmed by multiple tasks, and these emotions were clearly a barrier to teamwork. According to the participants in our study, being overwhelmed by tasks changes one's behaviour. A higher number of interruptions (for example, from phones or beepers) resulted in a significant lower SA for nurses and physicians working in the emergency department [169]. In our interviews, the MDs were predominantly the ones who talked about interruptions and clashes between tasks and conversations. The feeling of always having to have the answers to "everything" was overwhelming and created both frustration and stress, eventually having a negative impact on the MDs' performance. Earlier research has demonstrated that stress and anxiety correlate with negative team performance [23-25]. When observing MDs during work at the emergency department, Westbrook [170] found that interruptions and multitasking were associated with errors.

The most important findings from this research show that, for teams working in the ICU, teamwork and – in the end – performance is based on knowledge and behaviour. The findings in studies III and IV indicate that the concept of behaviour might be lacking in Endsley's model of SA. Therefore, we suggest that "behaviour" should be made visible in the existing model. Adding

behaviour to the SA model might contribute broader perspectives in education.

Is there a relationship between team background characteristics and team and task performances?

In Study II, it was found that higher age improved team performance, as measured using the TEAM instrument, affecting aspects such as teamwork, task management, team overall and total team performance. Furthermore, prior team training without video improved task performance. However, prior education in communication deteriorated leadership. It should be noted that these findings are based on cross-sectional data collection, so it is not possible to determine causality.

It is interesting that higher age, but not work experiences, improved several aspects of them performance in the initial analyses and in addition, the association still remained in the multiple linear regression analyses. In general, it is reported that higher age is related to more work experience [171]. I assume that the low power in the analyses probably will explain why work experiences were not significant with any of the dependent variables. Considering this, I will further discuss different aspects of team performance in relation to work experiences. More often than not, high competence is usually based on experienced-based knowledge, including tacit knowledge.

In general, higher age and greater work experience somewhat overlapped and associated with competence. In her review analysing nurses' decision-making, Nibbelink [172] stated that experience was an influencing and contributing factor towards increased SA and better decision-making. However, more detailed data collection about prior education and experience in our study would have been helpful in that discussion. Nevertheless, a discussion about the different aspects within the wide concept of competence in the context of teamwork and team performance is relevant. Anderson and Lingard [173] report that student nurses and MDs learn teamwork through socialization processes during their training. Lingard performed research in the area of teamwork within healthcare over a period of a decade. According to Lingard [173], three interesting phenomena can be seen when analysing competence from an individual perspective: (1) competent individuals can form an incompetent team; (2) individuals that perform completely in one team may not function in other teams; and (3) one incompetent member does not always impair all teams. A high level of teamwork is generally difficult to analyze as something an individual possesses. Rather it has a broader complexity in collaboration through collective competence, learning, and social interactions. Arndt [174] describes different socialization processes that build upon interprofessional work and practice. Interprofessional learning in the ICU comes from learning from another, learning together and learning about each other [175]. It has been stated that inexperience can result in fewer shared mental models; however, deliberated practice and training in team coordination, an accurate shared situation model can still be achieved [100].

Methodological considerations

In this thesis both quantitative and qualitative methods have been used to achieve the objectives of the studies, and to explore SA as well as team and task performance. The quantitative studies (I, II, III) were based on several approaches. In the first study, trustworthiness in different instruments was evaluated. The focus in this discussion is on validity, reliability as well as feasibility. Thereafter, a cross sectional study (Study II) was performed, with strengths and weaknesses in such designs is discussed. The intervention study (Study III) included several important steps, such as planning the intervention, the control and the outcomes, as well as the collaboration with different units at the two hospitals in order to invite participants. Finally, a major challenge in Study III was to implement the intervention and the control. In summary, Study I-III is discussed in respect to selected participants with focus on external validity and generalizability, as well as internal validity and reliability in the used instruments. I will also discuss the use of SBTT and implementation of the *in situ* simulation intervention. In the fourth study, I changed my focus from testing hypothesis to understanding a phenomenon. In respect to this, trustworthiness in Study IV will be discussed using concepts such as dependability, credibility and transferability. Throughout all studies in this thesis, I have reflected on my own position as a critical care nurse, my previous or preunderstanding and experiences of SBTT in relation to becoming a researcher.

Study I - reliability and feasibility tests of instruments

As pointed out above, Study I focused on testing the ABCDE checklist, the TEAM instrument and the development of two SAGAT questionnaires for reliability and feasibility.

With this in mind, it was important to include participants who had some experiences in teamwork during simulation training. Therefore, eligible medical students performing an ongoing SBTT sessions were included in Study I. This convenience sample strategy had several advantages. One was to select a well-defined group including both men and women of different ages and experiences from previously performed SBTT. Furthermore, the goal in Study I was not to test hypotheses or identify diseases, but instead to test instruments for trustworthiness before they were used in Study II and III. Thus, to generalize the results to a larger population was not a goal. In Study I, in order to later be used in Study II and III, the technique SAGAT were tested and analysed for feasibility and internal consistency, and the instruments TEAM and ABCDE for interrater reliability. The methodological strengths and weakness for these instruments and technique will be discussed below.

The instruments were tested in SBT as Study II and III were planned to be performed in a simulated setting. As well known, it can be difficult control the practical details when conducting research in clinical practice with patients. Advantages and a significant strength with research using a patient simulator is the possibilities to standardize cases, events and responses. SBTT has, for example, been used to test skills [43], educational concepts [77] and

instruments [83]. When analysing data collected from SBTT, the presence of the researcher and instructors in the same room as the participants is a specific consideration [176]. It is also relevant that performing in a simulated setting might change some behaviours, for example, some participants might increase their attention to the monitor [177].

SAGAT

The results in Study I showed that the SAGAT technique was feasibly to use during the simulation training. However, some challenges and difficulties in the SAGAT technique can be highlighted. Creating high quality queries is a challenge, as well as standardized scoring of open-ended answers. In addition to the right content (described below), a well-structured question is characterized by being short and consistent, without cues which might give away the correct answer. If it is a closed question, the alternatives are brief, and mutually exclusive [178].

When developing items for SAGAT, GDTS was used to create questions relevant for measuring the important goals of each scenario and to capture decisions. Endsley advocates that GDTS is efficient for clarifying objectives and should be used systematically in when preparing for different types of team training and developing SAGAT questions [14]. The combination of GDTS for defining the content in the query, a well-structured query and a process to review of the queries, together allowed for a good internal consistency, as shown in Study I. However, the technique relies on the development of specific queries for each scenario. Thus, some reliability tests, such as test-retest, are difficult to perform, since the questions are related to the specific scenario.

The validity of SAGAT deserves further consideration, and one question is whether or not SAGAT measures situation awareness or only tests factual recall. Is it a memory test [71]? Endsley [14] reported that valid results can be obtained with SAGAT and that the technique is sensitive to system manipulations. She also suggests a higher number of questions, 40, which in the clinical context of this study would create practical difficulties as far as time it takes to answer the questionnaire. A high number of questions increases the precision of the measurement while also increasing the time taken for the setup. Thus, the number of items needs to be balanced against feasibility. A lower number of questions makes it more difficult to measure internal consistency. In simulation contexts in healthcare, it is common to have fewer questions [83, 134]. In Study I, 22 questions were used. Depending on the GDTA-derived goals for the given scenario, the number of questions at each level might differ. For example, in case 2, level two questions (comprehension; n=4) were fewer than those for level three (projection; n=12), since the goals for the comprehension level were few. To capture SA, SAGAT queries aim to capture the immediate “gut reaction” response [179]. For this, the time available for answering the questions should be limited. This was implemented in Study I and III by limiting the amount of time for answering the questions. The organisation of the freeze in the scenario ensured that the questions were answered promptly by all participants. It was not possible for the participants to prepare specific answers in before.

Randomly freezing a scenario, in order to measure with SAGAT, has been reported to be a valid measurement of SA. But as suggested by Endsley [14] the first freeze was at least 5 minutes into the scenario, to allow for the participants to have a chance to understand what is going on. Then, there were at least 5 more minutes until the next freeze. Hogan et al [85] reported that freezing the scenario did not have a negative impact on performance, which is in line with the results in Study I. The experiences of the freezing event were positive, and participants rather saw the freeze as a chance to reevaluate the situation. Some pointed out that it would be useful to be able to do that in the clinical setting as well.

TEAM instrument

The TEAM instrument has demonstrated validity and reliability [92], and it has been shown to be a robust assessment scale [136, 180-181]. In my point of view there are several factors to consider in the choice of instrument. One advantage with the TEAM instrument is the overall assessments that enables a possibility to score by 'gut feeling´ and overall impression. In addition, the subscales measure leadership, teamwork and task management. The internal consistency as assessed with Cronbach's alpha has been reported high (0.97, 0.91, 0.92) in three different studies [84, 88, 92]. Another strength is that the tool has available support and explanations available for the scale anchors [92, 151]. It was a strength in our studies that the raters had the opportunity to view the recorded observational data several times. In Study I, the raters had different levels of experience, but the degree of agreement between the raters was high. In a recent study, Freitag and co-workers [182] reported similar results. The data collected from the video recorded material were of high quality with no hinders for observing different behaviours, collaboration and also hearing the conversations during the sessions.

ABCDE checklist

The ABCDE checklist was used to measure task skills within the ABCDE concept. The checklists items followed the well- established algorithm found in the ATLS system [138] which is commonly used for structured care in critical situations. The grading scale was designed to reflect both effectiveness and correctness. I Study I, the interrater reliability was good according to Koo [148]. A requirement or weakness with this kind of checklists is the need for adaptation to the specific clinical cases. This is in line with using GDTA to develop SAGAT questionnaires. In addition, depending on how the specific scenario evolves, the possibility for the team to achieve a certain score might be affected. For example, in Study III, one item in the ABCDE checklist was excluded in case 1. In case 1, the patient was conscious and could communicate verbally throughout the scenario. This rendered the item *secured airway* non-gradable. In summary, the ABCDE checklist used in this thesis has undergone extensive revisions from the original [137] since several items were case specific and also included team organization items. The scale is reliable, but it might be beneficial at some point to further establish the validity of the different items.

Study II and III – cross sectional and intervention

The generalizability of the findings in Study II and III depends on how the participants were included and if the sample represents a more general population. In Study II and III, all ICU personnel working close to patients, including medical doctors, registered nurses and enrolled nurses at two different hospitals and from two different counties, were invited to participate. The spread in age, gender, professions and in years in profession indicates that it might be representative for ICUs in general in Sweden. This comparison has not been made due to lack of published data on this personnel group. In addition, it is important to have in mind that the participants were not selected randomly out of the population in Sweden, thus, the generalizability of the findings in Study II and III are not obvious. Setting up a data collection to be able to answer this question was not within the scope of this thesis.

Another aspect of generalizability is whether the data has been collected in a way that replicated clinical work, or if the setting was too artificial to provoke usual clinical behaviour. However, the simulation is carried out in the ICU, with the patient simulator in a bed, connected to a patient monitoring system, using regular syringe pumps to deliver pharmaceuticals, a regular ventilator when needed, and more. Suspension of disbelief is essential for participants to engage in a realistic clinical scenario. In Study IV, where the data was collected after Study III, the participants promoted team training as a way to obtain guidance from more experienced team members, and to improve one's own performance. This indicates that learning in the training was transferable into a clinical work context.

The aim with the intervention study in this thesis was to evaluate an educational program developed for increasing knowledge and skills in obtaining SA. A specific aim was to assess if it could be transferable to daily clinical practice. It has been postulated that when training technical skills, NTS and building interprofessional competencies, SBT can be a powerful method [183]. By performing the simulation sessions *in situ* at the ICU, using scenarios with a high level of realism, the study aimed to facilitate implementation at the top of the Miller's pyramid. In addition, *in situ* simulations has been suggested as a feasible way to assess ICU competences [184].

Study II was based on cross sectional data, or data collected at one specific time. That provided a possibility to study several variables at the same time, but with the limitation that causality is not possible to assess. In Study III, the teams from Study II, from both hospitals, were randomly allocated to intervention and control groups. The randomization aimed to distribute differences in background characteristics approximately equally between the groups. The team composition mirrored the normal process for scheduling in the clinic. Thus, the randomization of the teams allows for measuring the effect of the intervention while the strategy for assembling the teams increased the generalizability into clinical practice.

The power analysis indicated that a minimum of 22 teams would be needed to achieve a power of 80% at an alpha level of 0.05, based upon a predicted change of 1.0 in mean item score for the TEAM instrument with a SD of 0.91. This was based on a mean score of 2.49 and SD 0.91 from Cooper et al [92]. However, the number of dropouts from Study II to Study III is indeed a weakness. This decreased the power of the study and increased the risk of type II error, or the risk for non-rejection of a false null hypothesis.

A lesson learned from this project was that doing research in a clinical context which is highly researcher intensive for gathering data presents practical challenges. In the initial plans for this project, a third arm was planned as well as a 6 month follow-up. A third arm in the randomization would have aimed to further investigate the additional effect of using recorded video from the scenarios during the debriefing sessions, as suggested by Phelbs et al [185]. In addition, a 6 month follow up was planned to measure retention of skills since some degradation over time is expected [186-187]. However, high workload and difficulties in scheduling made these two additions unfeasible.

It was the scoring of behaviours shown during the *in situ* simulation as a marker for team and task performance combination with quantification of the participants SA (SAGAT), which allowed for analysing the research question. However, the use of these aggregated measures might be too insensitive to identify if the right task is corrected performed at the right time by the right individual. In addition, for a task to be performed in an optimal way, ideally the whole team needs to be involved in the decision making process [188].

Study IV - qualitative research

In qualitative research, trustworthiness is a central aspect. In order to achieve trustworthiness, credibility, transferability and dependability must be considered [153- 154]. The content analysis was chosen with the intention of exploring each participants' experiences of teamwork. Before conducting the interview, issues such as the effect of interviewing the participants in the researcher's own organization, as well as one's own experience, had to be processed and managed [189]. To achieve credibility, the research questions were transparent to the participants, and transcription of the interviews was approved by the participants at the end of the interview. To achieve credibility and transferability, the focus groups were separated by professions in order to make it easier for the participants to express opinions specific to each profession. The participants in this study varied in work experience, age and sex. To achieve dependability during the analysis process and for interpretation of the data, the results were presented and discussed in the research group. A strength of the data analysis was the interprofessional research group, which included members with experience in both nursing and medicine. This was an important aspect throughout the analytical process.

Conclusion and implications for practice

This thesis contributes to improvement and development of teamwork and team performance by focussing the cognitive aspect of NTS, and how to

enhance SA. I hope that the results presented in this thesis will contribute to further development of educational programs aiming to create safer patient care in acute and stressful medical situations at the ICU and similar settings.

Both international [190] and national statements [18] have supported the idea that a common factor in adverse events occurring in healthcare and the ICU is the failure of NTS. Interventional studies have been requested [191]. This thesis is an exploration and evaluation of the implementation of an educational programme promoting SA, which is a part of NTS. The results show that team leadership and task management was improved by the educational programme during *in situ* scenariobased training. Further, an important aspect of functional teamwork is the interdependencies between team members, creating the need for a balance between knowing how and behaviours in the team.

SBT training is expensive, given that it is expensive to take nurses, enrolled nurses and physicians away from patient care for non-patient care activities. Still, reducing unnecessary suffering for patients through steadily improving team practice is an important responsibility, not only for nurses but for all healthcare professionals, and thus for the healthcare system. It has been reported that having simulation educators and instructors working in clinical teams is also beneficial, since it facilitates spread of evidence-based knowledge, development of a reflective climate, and improved communication [192].

When implementing new educational programmes in clinical practice it is necessary to evaluate the outcomes. In a review analysing the implementation of CRM training, Maynard [57] promoted using several outcome variables and the importance measuring not only at an individual level, but also at team and organizational level. In CRM training, the focus is on team processes, with the aim of facilitating ongoing loops of evaluation and feedback. The tools used in this thesis aims to evaluate skills and behaviours at a team level. These might be used also in clinical after-action reviews to facilitate the development from novice to expert.

The results in this thesis demonstrate that both knowledge and behaviours are necessary for efficient teamwork in the ICU. Practicing skills and behaviours, as well as implementing SA - in interprofessional critical care training sessions, is a strong way to bring about positive effects on team performance in the clinical work.

Further research

During my PhD, new questions arose.

Further studies of SA, as a part of NTS, are needed in interprofessional milieus, both in simulated and clinical settings. For increased generalizability, multicentre studies are needed. The participating teams should have different professional experiences in order to widen the range of examples studied.

The relation between individual's working memory and SA have to be further investigated. There seem to be predictable relations between

attention, working memory, stress, performance and the different levels of SA. For this, instruments and techniques for observing and measuring individual and team SA in a clinical context need to be developed.

A future important research question is where in the scenario a participant gives their attention is eye-tracking equipment. Eye-tracking equipment is used to study interventions in the working environment aiming to increase SA. The method has been used in order to evaluate new ways of showing information. That is important for specific clinical situations as compared to the standard today where patient monitors show a standardized but broad set of information. This might be further enhanced by displaying information through an individual's eyeglasses, instead of on the patient monitor. Perhaps, in the future, the relevant information for each patient can be presented on a head-up-display when the physician or nurse looks at a specific patient.

Another topic of interest is huddle meetings which recently has emerged to increase SA in staff, and positive results of this are expected [193] with improved teamwork and collaboration. It is a brief meeting at the start of the day where the team is updated about the current status at the ward, trying to identify patients at risk. Longitudinal studies of the effects of implementing huddle meeting using outcomes on the organization, and specifically on patient care, are not yet available.

In addition, I believe that knowledge about the different levels of SA would be useful when analysing adverse events and errors in healthcare. It has been shown that these errors tend to be in SA level 1 [194], but there are currently no studies examining the effect of specific educational interventions aimed to improve SA level 1.

In summary, to further investigate how to improve the knowledge about SA in interprofessional teams, as well as the effect of these educational programmes, more extensive interventions studies are needed, most likely multicenter studies. Further, there is a multitude of paths open for exploration of how SA is established, maintained and thereby might improve team performance.

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