Open the door to complexity
– safety climate and work processes in the operating room

To
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CAMILLA GÖRAS

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Abstract

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A complex adaptive system such as the operating room (OR), consists of different safety cultures, sub-cultures and ways of working. When measuring, a strong safety climate has been associated with lower rates of surgical complications. Teamwork is an important factor of safety climate. Discrepancies among professionals' perceptions of teamwork climate exists. Hence it seems crucial to explore if diversity exists in the perception of factors related to safety climate and between managers and front-line staff in the OR. Complex work processes including multitasking and interruptions are other challenges with potential effect on patient safety. However, multitasking and interruptions may have positive impact on patient safety, but are not well understood in clinical work. Despite challenges a lot of things go well in the OR. Thus, the overall aim of this thesis was to evaluate an instrument for assessing safety climate, to describe and compare perceptions of safety climate, and to explore the complexity of work processes in the OR.

To evaluate the Safety Attitudes Questionnaire-operating room (SAQ-OR) version and elicit estimations of the surgical team a cross-sectional study design was used. How work was done was studied by observations using the Work Observation Method by Activity Timing and by group interviews with OR professionals.

The results show that the SAQ-OR is a relatively acceptable instrument to assess perceptions of safety climate within Swedish ORs. OR professionals´ perceptions of safety climate showed variations and some weak areas which cohered fairly well with managers' estimations. Work in the OR was found to be complex and consisting of multiple tasks where communication was most frequent. Multitasking and interruptions, mostly followed by communication, were common. This reflects interactions and adaptations common for a complex adaptive system. Managing complexity and creating safe care in the OR was described as a process of planning and preparing for the expected and preparedness to be able to adapt to the unexpected.

Keywords: patient safety, operating room, complexity, safety climate, psychometrics, cross-sectional, observations and qualitative

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LIST OF ABBREVIATIONS

CAS	Complex adaptive systems
CI	Confidence interval
CFA	Confirmatory factor analysis
CFI	Comparative fit index
CVI	Content validity index
ED	Emergency department
ICC	Intra-class correlation
ICU	Intensive care unit
I-CVI	Item-level content validity index
IRR	Inter-rater reliability
LPN	Licensed practical nurse
OR	Operating room
ORN	Operating room nurse
RMSEA	Root mean square error of approximation
RNA	Registered nurse anesthetist
SAQ-OR	Safety Attitudes Questionnaire-operating room
SRMR	Standardized root mean square residual
WOMBAT	Work Observation Method By Activity Timing

LIST OF PAPERS

This thesis is based on the following five papers, which are referred to in the text by their Roman numerals:

I. **Göras C**, Wallentin F.Y, Nilsson U, Ehrenberg A. Swedish translation and psychometric testing of the safety attitudes questionnaire (operating room version). *BMC Health Services Research* 2013;13(104):1-7.

II. Nilsson U. **Göras C**, Wallentin F.Y, Ehrenberg A, Unbeck M. The Swedish Safety Attitudes Questionnaire-Operating Room version: psychometric properties in the surgical team. *Journal of PeriAnesthesia Nursing* 2018;33(6):935-945.

III. **Göras C**, Unbeck M, Nilsson U, Ehrenberg A. Interprofessional team assessments of the patient safety climate in Swedish operating rooms: a cross-sectional survey. *BMJ Open* 2017;7(9):1-8.

IV. **Göras C**, Olin K, Unbeck M, Pukk-Härenstam K, Ehrenberg A, Kassaye Tessma M, Nilsson U, Ekstedt, M. Tasks, multitasking and interruptions among the surgical team in the operating room: a prospective observational study. Accepted for publication in *BMJ Open*, March 2019.

V. **Göras C**, Nilsson U, Ekstedt M, Unbeck M, Ehrenberg, A. Managing complexity in the operating room: a group interview study. In manuscript.

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PREFACE

From the early beginning of my working career in healthcare, I knew that I wanted to become a registered nurse anesthetist (RNA). However, before entering Örebro University to become a specialist in anesthetic care nursing, I worked for a year and a half as a registered nurse specializing in infectious diseases. As septic patients can have unstable vital signs, this turned out to be a very useful experience when managing today's work in the operating room (OR).

During my first year as an RNA, I learned a lot about the importance of teams and quality of teamwork. I realized how important interaction and communication between team members are for a safe, efficient, and seamless care process. My sparse experience meant that I also experienced a high level of stress, challenges such as a feeling of always being one step behind, and sometimes gaps in continuity of care due to lack of information. Eight years ago, this experience inspired me to explore how the work environment can influence patient safety. However, at that time I could not imagine that patient safety was such a complex field, with the work environment forming just one important component of a large healthcare system. Without understanding it, I likely already felt the sense of working in a complex system. Today, I know that in our daily work as healthcare professionals we manage complexity but we might not always see it!

Patients in the OR are vulnerable and may suffer from several co-morbidities. At the same time professionals have to handle other challenges, such as conflicting goals between productivity and safety, which may have an impact on the ability to deliver safe care. Despite these challenges, a lot of things go well. Studying the OR enables us to understand how safety climate is perceived by different professional sub-cultures and managers, and the work processes and how work is done in the OR are also of interest. Besides being a PhD student, since 2015 I have been working part time at the Department of Anesthesia and Intensive Care Unit at Falu Hospital as a patient safety coordinator, which can be seen as an advantage when linking theory to practice. From the perspective of complexity, this thesis will contribute with knowledge about contextual challenges in the OR.

INTRODUCTION

A fictive patient case in a complex adaptive system

A 78-years-old patient arrives at the emergency department (ED) with a knee fracture and is scheduled for acute orthopaedic surgery. The patient recovers from the procedure and returns home. After four weeks, the patient is still experiencing leg pain and a lack of wound healing, and returns to the orthopaedic ward, for further examinations. The medical examination reveals a diagnosis of critical limb ischemia and the patient is scheduled for acute vascular surgery. The surgical procedure takes six hours. In terms of recovery, the patient belongs to the vascular specialty and is transferred to the surgical department. One week later the patient is considered medically cleared from the vascular treatment and is transferred back to the orthopaedic ward. After another week, healing of the knee wound still lacks of progress. The patient is scheduled for a knee surgery, and is preoperatively assessed by a physician from another specialty who is on a three-month anesthesia internship. The preoperative assessment documentation provides sparse description of the patient´s status. On the day of surgery, the surgeon reads the documentation, prepares for the procedure and anticipates potential situations. The operating room nurse (ORN) and licensed practical nurse (LPN) also prepare by reading and anticipating what could happen and what might be needed. The RNA starts working 30 minutes later than the other members of the surgical team, who transfer their information to the RNA. The RNA then continues preparing according to plan, checks all the equipment and reads the patient record, ten pages of information, together with other additional information. However, the RNA finds that the patient's haemoglobin value was <90 g/l and no compatibility test has been performed. During patient handover from the ward, information was given that routines for the planned procedure did not include performing a compatibility test. The clinical experience of the surgical team allows them to adapt to this new situation and discuss potential risks and respond to changing conditions. Necessary tests were added, in case of the need for blood transfusion. When positioning the patient, the ORN and LPN carefully talk to the patient to identify other potential risks. At the same time, an RNA student arrives unannounced; the RNA adapts to the situation and explains the case, and together they prepare the patient with a large peripheral venous catheter. During the briefing of the surgical safety checklist, no information about previous surgery is brought up in the team. Intraoperatively, the surgeon is interrupted by a malfunctioning X-ray machine. While the equipment is being changed, the surgeon is interrupted again by a call from a junior colleague at the ED who needs decision support about a patient. As the surgical procedure continues, the RNA reads the patient record more thoroughly and notices the previously performed vascular surgery and a note that the patient suffers from severe vascular disease. The rest of the surgical team is informed, the unexpected situation is shared and discussed, and the team is prepared for a potential blood loss from anticoagulant treatment from previous surgery. When arriving at the postoperative recovery unit, intraoperatively the patient had a blood loss of >1400 ml and had been transfused with four blood units, is circularly stable, has a haemoglobin value of approximately 100 g/l and feels relatively well. Despite the challenges, stemming from the specific characteristics of a complex adaptive system such as healthcare, the procedure has gone well for the patient, which to a great extent was due to the skills and adaptations of the professionals in the OR.

BACKGROUND

Healthcare is a large and effective system, often described as a complex adaptive system (CAS) characterized by emergent behavior, which makes it difficult to observe the effect of interactions and adaptations as they constantly develop. A CAS is defined as "*a collection of individual agents with freedom to act in ways that are not always totally predictable and whose actions are interconnected*" (p.651), such as a surgical team.[1] Healthcare systems are composed of many interacting professionals, patients, managers and policymakers, artifacts, equipment, and technologies.[2] In some countries, such as Sweden, safety management of a complex healthcare system, can include several challenges[3]; that is, an aging population, co-morbidities, human resource constraints, and reduction of patient beds.[4]

Patient safety is a property of a system with many target areas, such as adverse events, infection control, and safer surgery.[5] [6] The increasing complexity of modern healthcare create challenges for traditional safety management strategies.[7] Healthcare is changing, and is now faced with the challenge of achieving higher levels of patient safety while improving quality and decreasing costs.[8] Complexity can also be an obstacle to improvement, as layers of barriers, such as technical safety solutions or administrative checks, are designed to both filter harmful consequences and transmit desired results. However, barriers can increase the interactions and complexity, which makes the system more difficult to describe, more intractable and less amenable to improving patient safety. Unlike aviation industry, healthcare is a CAS that involves a large number of employees, facilities, technologies, types of knowledge, and skills. It is not an engineered system, but instead has been shaped by human activity over time. Patient safety mostly comes through interactions, for example between team members and organizations. It is not a property of a single component; it is a product and a result of interactions between components, material, and ongoing processes such as those that take place in the operating room (OR).[9]

Worldwide, it has been estimated that 312.9 million surgical procedures were performed in 2012.[10] In Sweden, approximately 2.7 million surgical procedures was conducted in 2013.[11] [12] The OR context is often described as complex, dynamic and involving high cognitive demands.[13] It consists of different professionals and social structures with various priorities and goals that are constantly revised and rearranged. Anticipating the future is mostly the task of professionals "at the sharp-end"; that is, the surgical team. Other characteristics of a CAS include specializations, for example by professionals, and advanced medical-technical equipment such as robotic-assisted laparoscopic surgery machines.[14] This is also expressed in the patient case described above, with multidisciplinary team that has to interact with other professionals and advanced equipment. The work in the OR is highly dependent on the surgical team, which consists of different disciplines. Given their non-linear interactions with other team members and the surrounding environment, teams in healthcare have also been described as a CAS.[15] Within multi-specialty ORs, groups of professionals are assigned into various working groups depending on priority, context and surgical procedure. Different group interactions are described for example as ad-hoc teams, which for some can be perceived as challenging.[16] Professional sub-cultures and a lack of understanding from other team members can create challenges with team information transfer. Support and resources are seldom optimal which may produce strain among staff and lead them to develop compensatory strategies.[17] Control is made more difficult by the uncertainty stemming from variations, the surgical procedure in itself, and patients with complex diseases.[18] Procedures are often performed under time pressure,[19] and the work process is a subject to demands for increased efficiency and production pressure.[20] The OR context, is also an arena with potential for multitasking and interruptions, which again is expressed in the patient case above.[21] In order to deliver safe care, surgical teams need to adapt to the continuously variable and changing environment.[15] To study how daily work is managed in this context could benefit from being viewed as a CAS, in the light of complexity theory.

Understanding patient safety

This thesis takes its starting point in understanding healthcare delivery in the OR through the conceptual lens of *complexity theory,* as a *complex adaptive system* in which patients and professionals work together to manage the daily tasks. As exemplified in the above-described patient case, a CAS is a collection of individuals, for example a surgical team, with the potential to act in unpredictable ways and whose actions are interconnected. A CAS, consists of several subsystems and organizations with different *safety cultures* and ways of working. To aid understanding of the contextual challenges that arise when practicing patient safety in the OR, the background is presented below in two main sections. The first section, *Understanding patient safety,* provides a theoretical perspective by describing important theories that may have an impact on patient safety in healthcare. The second section, *Patient safety in operating room practice* describes context-specific perspectives of relevant concepts, reflecting a CAS with a diverse impact on patient safety in the OR. The key concepts which are important for patient safety and used in this thesis are defined in Table 1.

Table 1. Key concepts and definitions important for patient safety

Key concepts	Definitions
Complexity	Complexity emerges as a result of the patterns of interaction between elements[22]
Complex adaptive system	A collection of individual agents (teams) with freedom to act in ways that are not always totally predictable and whose actions are interconnected, for example a colony of termites or a surgical team[1]
Interruption	An observable external stimulus resulting in a change of task [23]
Multitasking	Conducting two tasks in parallel[23]
Resilience engineering	The art of managing the unexpected or how a team or organization becomes prepared to cope with surprises. Resilience engineering assesses changes in the adaptive capacity of an organization as it confronts disruptions, change and pressures[24]
Resilience	The intrinsic ability of a system to adjust its functioning prior to, during or following changes or disturbances, so that required operations can be sustained under expected and unexpected conditions[25]
Safety culture	The shared values, attitudes, and behavioral norms that determine the degree to which all organizational members direct their attention and action toward minimizing patient harm during delivery of care[26]
Safety climate	The shared perceptions of how managers act and how "we all", as members of a work group, act in relation to safety, but also shared perceptions of management values through overt manifestations of these values[27]
System	A model used to understand the world around us. The essence is its elements, i.e. a group of parts and the relations between these parts through which they function together and form a whole in terms of a system[28]
System perspective	Concepts and principles to interpret how different elements and subsystems can interact and affect each other within a limited whole[9]

Complexity theory and complex adaptive systems

Complexity is described as a characteristic of a system.[29] The epistemological assumption of complexity is dependent on how the system is defined by the description of a system that is intractable, difficult to describe, rather than tractable.[30] Complexity theory is a post-Newtonian paradigm that originates from reactions to the reductionist assumptions. The Newtonian paradigm has supported science for centuries, and is mostly characterized by breaking down complex phenomena into isolated objects that are assumed to interact in linear and predictable, cause and effect chains.[31] When these isolated objects are reassembled, the whole system can only be understood as the sum of its isolated parts.[28] If lack of patient safety is viewed as a complex phenomenon, the relationship between the behavior of parts in the system and outcomes at the system-level is no longer obvious. Thus, the previous focus on malfunctions or human errors is not the only solution to a complex problem. According to complexity theory, system behaviors emerge from multidimensional relationships and interconnections deep in the system and cannot be reduced to their individual parts.[31]

In our working lives, we act as a part of a complex system. A system is a model used to understand the world around us. The essence is its elements; that is, a group of parts and the relations between these parts through which they function together and form a whole system.[28] The term "complex" is often used when something is complicated or difficult to understand, or involves multiple actions. However, being complex is not the same as being complicated, as complexity arises from interactions between structurally connected elements.[32] According to Cillier,[22] complexity *"emerges as a result of the patterns of interaction between the elements"* (p.5), and is often characterized by a number of principles used to interpret non-linear and dynamic systems; that is a CAS.[33] These principles can be understood as *number of elements* in a system. A society is more complex than a group, as it has subsystems with elements that interact at various levels. A low level of connection between elements can be described by individual properties, whereas with increasing interactions the relations between elements increase the *degree of connectivity* within the system. *Adaptive behavior* means that elements are capable of adapting over time; this also increases the complexity, as exemplified in the patient case described in the introduction when the team rapidly responds and adapts to the unexpected situation. Adaptation also means that elements can self-organize, which allows for the emergence of the organization from the bottom-up; that is, individual elements interact and form new intractable patterns in the whole system. The greater the *degree of diversity* between elements in a system — that is, the greater the diversity between parts — the more complex and abstract the systems become to capture common functions.[28] Most people are not aware of the complexity that emerges from their interactions; in other words, "*they do complexity but they don't see it*" (p.17).[34]

The use of complexity theory in healthcare has increased in recent decades.[34 35] Complexity theory has been used in relation to interactions and relationships and for conceptualizing work environments and variables or as a framework for analysis.[35] Research has illustrated how the OR and the surgical team have the components of a CAS.[1 14] As the patient case in the introduction section indicates, the degree of connectivity in a CAS (shared guidelines between the ward and OR) requires an individual perspective on the patient and interactions between professionals and different organizations. Although complexity theory acknowledges the need for regulation, the behavior of these systems, cannot be controlled by simply adding more regulations, as this may create more barriers and deviations from expected results and increase the complexity.[36] However, when gaps in continuity of care occur,[37] the case shows how OR professionals anticipate and cope with complexity by adapting to unexpected situations. A review revealed that, several studies, including some in the healthcare field, proposed resilience as a way of coping with the challenges of working in a CAS.[38]

Perspectives on patient safety

Today's patient safety knowledge has emerged from safety science in other industries such as nuclear power plants, which have been exposed to major accidents.[39] Practicing patient safety requires an understanding of different approaches of patient safety. A definition of patient safety comes from the World Health Organization, which defines it as the prevention of errors and adverse effects to patients associated with health care.[40] However, there are also several other definitions. Most of these definitions focus on accidents and errors, and patient safety is defined by its opposite; that is, lack of safety. Defining patient safety as a condition where nothing goes wrong has an impact on daily practice, as focusing on what goes wrong does not help in understanding why things went well. For example, if the probability of failure is 1 in 10 000, this could instead be formulated as an expectation of success in 9 999 of 10 000 cases. Even in healthcare, where depending on how failures are counted the failure rate can be more like a few percent up to 10 percent, most things go right.[41] Patient safety efforts from the view of avoiding anything going wrong (also called safety I), are usually triggered by harm or unexpected outcomes. The larger the event, the more extensive the response, and the aim is to prevent it from happening again by identifying the underlying causes. This involves comparing what actually happened (work-as-done) to what, according to prescriptions, should have happened (work-as-imagined).[41] Work-As-Done differs significantly from work-as-imagined, as by definition it reflects the reality healthcare professionals have to deal with.[42] As shown in the patient case, a CAS not only performs reliably because of guidelines or perfectly designed processes, but also because people are adaptive and flexible.[42] Understanding the contextual challenges of today's healthcare requires a focus on how work is done in everyday clinical work.[43]

From a system perspective, as early as 1998 safety was emphasized as *"a characteristic of systems and not of their components. Safety is an emergent property of systems"* (p.157).[44] Furthermore, patient safety has been defined as: *"a system property that arises from the interactions that take place within the system"* (p.145) [author's translation from Swedish].[9] Compared to others, these definitions not only describe the importance of a system perspective and interactions for safety but also the complexity of the healthcare system. From this perspective, safety efforts lead naturally to a different approach: ensuring that things go right (also called safety II). The focus is on what actually happens when "nothing" happens. People learn to recognize when something is about to go wrong, and compensate for malfunctions in the system by recognizing demands and challenges and adjusting their performance to various conditions to achieve safety and productivity. Safety management means understanding work-as-done and performance variability.[41] However, research suggests that the safety I and II perspectives must co-exist and safety management must act both reactively and proactively.[45] Working proactively; that is, looking at what could happen and ensuring that resources are available, requires knowledge about how the system develops and changes, and how its functions affect each other. This is achieved by looking at relations and patterns across events rather than components in single events.[41] In line with the safety II approach,[30] resilience engineering claims that things go well because people adjust their performance to match actual work conditions.[46]

Resilience engineering - a theoretical perspective

From a theoretical perspective, resilience refers to a system's ability to absorb changes and to be able to return to equilibrium.[30] A review found that healthcare was one domain where different resilience areas were studied, such as identification of resilience, theory, and training.[47] Resilience engineering has been advocated as a safety management paradigm for conceptualizing how work is accomplished in a CAS, and emphasizes resilience at the organizational, team, and individual levels.[48] Resilience engineering stems from cognitive systems engineering,[25] and was developed from risk assessment and system safety.[48] Woods,[49] described resilience and resilience engineering as, *"the art of managing the unexpected or how a team or organization becomes prepared to cope with surprises. Resilience comes from the Latin resilire – 'to leap back,' and denotes a system property characterized by the ability to recover from challenges or disrupting events. Resilience engineering assesses changes in the adaptive capacity of an organization as it confronts disruptions, change, and pressures"* (p.1). On the other hand, one theorist argues that organizations need to respond to both expected and unexpected disruptions.[3] Hollnagel, defined resilience as, *"the intrinsic ability of a system to adjust its functioning prior to, during or following changes or disturbances, so that required operations can be sustained under expected and unexpected conditions"* (p.xxxvi).[25] To conclude, Hollnagel's definition emphasizes the need to react and respond not only when disturbances occur, but also when they are anticipated to happen,[50] which is also exemplified in the patient case. The RNA did not follow the guidelines, but instead performed an individual assessment. This thesis takes its standpoint in Hollnagel's definition.

As noted, there is a lack of conceptual clarity and the operationalization of the concept is still in an explorative phase.[47] Resilience engineering describes how success and failure come from the same underlying processes; different outcomes are dependent on how organizations and people cope with complex and unpredictable environments. It is an alternative to traditional safety management, with its focus on failure as a malfunction of normal performance. However, normal performance requires people and organizations to adjust their activities to meet current work conditions, by prioritizing and making trade-offs between efficiency and thoroughness. This is also exemplified in the patient case, when one profession started working 30 minutes later than the others. To save time, the team shared information and the solid patient record was initially read only briefly. Since information, resources, and time are usually are limited, adjustments are needed and performance becomes variable.[43] This may be of minor importance when there are no perturbations, but variations, interruptions and disturbances are common in a CAS.[2 43 51] When variations and interruptions lead to disturbances, this may predispose for unwanted outcomes such as performance variability, which may be combined in unexpected ways and increase the complexity.[43]

A resilient organization can anticipate, adapt, and learn from variations and disturbances.[52] Resilience has been found in different healthcare domains including ORs, EDs, and intensive care units (ICUs),[51] and may benefit from resilience engineering.[2 43 51] The work of the surgical team (the operating point), is influenced by its system boundaries, when for example increased production pressure, they are pushed away from workload but instead towards the accident boundary. The complexity and dynamic properties of a CAS makes the operating point move constantly, as expressed in the patient case when the patient arrived in the OR for a surgical procedure with a fairly low hemoglobin value. Instantly the operating point was moved towards the accident boundary. The system operating point and accident boundary are vital but difficult to identify, as boundaries are often invisible. However, a safety culture exists when management and professionals are aware of the margin of safety and able to detect the system's accident boundary and boundary to performance failure,[53 54] illustrated in Figure 1.

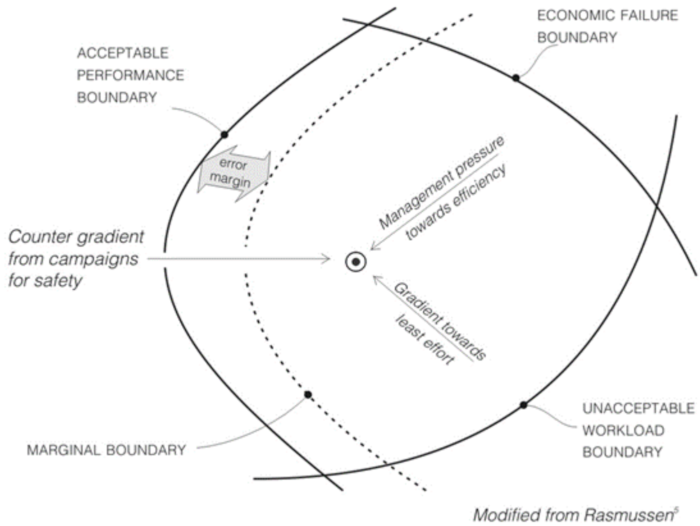

Figure 1. Rasmussen's dynamic safety model illustrating how a system can operate safely inside the boundaries under constant threat of drifting towards the boundary to performance failure (presented with permission from Richard Cook).[53 54]

Organizational culture and organizational climate

Culture is an influential structure in the organization, created by interactions with others.[55] In the 1970s, research was undertaken on the concept of organizational climate, which has its origins in psychology. Schein,[55] describes organizational climate as cultural assumptions, referred to as shared perceptions of the procedures, practices, and kinds of behaviors that are rewarded and supported with regard to a specific strategic focus.[56] Organizational culture is the broader concept, and has its origins in anthropology.[57] A CAS also consists of an organizational culture with its specific organizational climate. Organizational culture is difficult to measure, analyze, and manage, but was defined by Schein[55] as a *"A pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore to be taught to new members as the correct way to perceive, think and feel in relation to those problems"* (p.18). As early as 1975, Schneider[57] claimed that safety climate should be one of the strategic goals of an organization, which was supported in 1980 by Zohar's research on safety climate.[58]

Safety culture and safety climate

Safety culture emerged in the aftermath of the 1986 Chernobyl accident, where human and organizational factors appeared as important aspects to previous focus on technology as the cause to an accident.[39] The concepts and definitions of safety culture and safety climate are many and intermingled.[59] Between 1980-1997, 16 different definitions of safety culture and climate have been described.[60] These concepts are subsets of organizational culture and climate,[58] and safety culture should be viewed as a subset of organizational culture; that is, beliefs associated with safety.[61] Safety culture is a component in safety management within several high-risk industries, including nuclear power production and aviation.[61] In healthcare, safety culture encompasses the shared values, attitudes, and behavioral norms that determine the degree to which all organizational members direct their attention and action toward minimizing patient harm during delivery of care.[26]

The concept of safety climate was introduced by empirical studies in industrial organizations.[58] Safety culture and safety climate are related,[27] and it is argued that safety climate captures the surface features,[62] or measurable components of safety culture.[63] Zohar,[64] stated that safety climate refers to the shared perceptions of existing safety policies, procedures and practices. Safety climate has also been defined as the "*shared perceptions of how managers act and how "we all", as members of a work group, act in relation to safety, but also shared perceptions of management values through overt manifestations of these values*" (p.6).[27] This thesis uses both terms: safety culture and safety climate. Safety culture will be used when describing shared values in general. When describing specific measurements related to conducted research, the term "safety climate" will be used according to the definition that safety climate consists of employee´s perception´s, attitudes, and beliefs about risk and safety.[65] The levels and relations between the above-described concepts are presented in Figure 2.

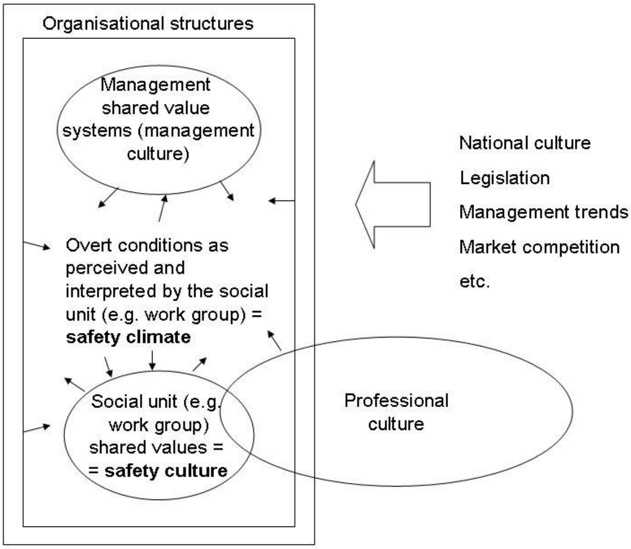

Figure 2. Conceptual and contextual framework of safety climate in relation to safety culture, management culture, professional culture, organizational structures, and surrounding parameters (presented with permission from Marianne Törner).[27]

In order to understand and improve safety, safety culture is an important area of focus in various high-risk industries.[66] In healthcare, developing and promoting a patient safety culture is now a core element in improving patient safety and quality of care.[67 68] Aspects which increase safety culture include leadership, teamwork, evidence-based work, communication, learning, and patient-centered care.[69] Patient safety culture is influenced and driven by leadership,[44 69] and senior leadership is the key factor in fostering and nurturing a safety culture. Engaged leaders facilitate this culture by designing strategies and building structures that guide safety processes and outcomes.[69] Hospitals with higher levels of safety culture, have been shown to also have a higher safety performance from professionals.[70] To build a safety culture in the OR, the team must have an open dialogue and understand expectations of others in the team, which in turn is dependent on the organizational culture.[71]

When reviewing the literature, studies show inconsistent outcomes; some find associations between safety culture and patient outcomes[72 73] while others do not.[74] A systematic review looking at positive organizational and workplace cultures (in relation to positive patient outcomes) showed associations between a positive culture and reduced mortality rates, falls, hospital acquired infections and increased patient satisfaction.[75] A research scan that examined if improved safety climate affected patient-related outcomes, (readmission rates, length of stay, mortality, complications, medication errors and adverse events) found a lack of associations.[74] A four-year comprehensive patient safety program focusing on aspects such as improved teamwork, best practices, and understanding safety science was found to improve safety climate and decrease patient-harm and severity-adjusted mortality.[76] A review, focusing on safety climate and patient outcomes found existing relationships at the hospital and unit-level. However, nurse-sensitive outcomes showed inconsistent relationships, one study found a positive relationship between safety climate and patient falls whereas another study showed non-significant results.[77] Another review including 17 studies found no consistent relationship between safety culture and quality care outcomes.[78]

Patient safety in operating room practice

Progress in patient safety and surgical safety

From a historical view, patient safety has been the main focus for the past two decades. A time line shows a brief historical overview of the international development of patient safety from 1995 and forward, moving from risk management to complexity, Figure 3.[67]

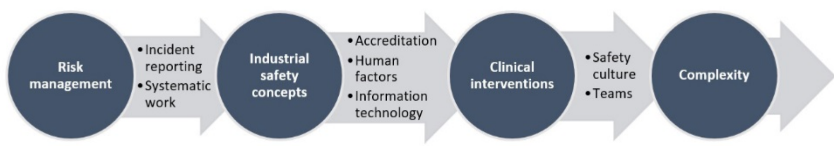

Figure 3. An overview of the international progress in patient safety from 1995 and forward

Substantial progress in patient safety has been made in surgical care, including the OR. The World Health Organization Surgical Safety Checklist was introduced in 2008, and resulted in a reduction of patient complications and mortality.[79] Ten years after the introduction of the checklist, it was declared that communication and teamwork had improved.[80] Introduction of the, Surgical Patient Safety System (SURPASS),[81] where checklists and other communication tools are included along the surgical pathway, produced a reduction in surgical complications and mortality. Another programme, enhanced recovery after surgery, (ERAS) has been introduced to improve patient care and shorten hospital stay following colorectal surgery. The programme resulted in significantly shorter lengths of stay for patients enrolled in the ERAS concept.[82] Despite these results some researchers argue that safety problems still remain,[83] checklists alone are not sufficient, as the ideal situations seldom appear in complex systems. For example, promoting a positive safety culture by teamwork, leadership commitment, and having a system perspective seems crucial to achieve further progress in patent safety.[84]

Safety climate in the OR

Measuring safety climate

A few studies have assessed the associations between safety climate and surgical outcomes. A weak safety climate in the OR was associated with higher rates of surgical complications,[72] while a strong safety climate in a surgical unit was associated with a lower incidence of surgical site infections. In the latter study, a positive safety and teamwork climate and an engaged hospital management were concluded to play an important role in surgical outcomes.[73] Several tools exist for measuring safety climate.[85] The Hospital Survey on Patient Safety Culture (HSOPS) and the six-factor Safety Attitudes Questionnaire (SAQ), have repeatedly been mentioned in reviews as the most highly recommended tools,[59 86] based on their robust psychometric properties.[85] A review of methods to quantify teamwork in the OR also concluded that the SAQ was the most robust self-assessment tool, despite its failure to demonstrate multisite reliability.[87] Safety climate scores in the SAQ have been shown to correlate with patient outcomes.[77] The SAQ has been adapted for use in different settings such as the ICU,[88] ambulatory clinics,[89] and the OR.[90] The different versions of the SAQ have been translated into several languages and tested for their psychometric properties.[91-94] In early 2010, the generic version of the SAQ was adapted and tested for use in community pharmacies in Sweden.[95]

Perceptions of safety climate

Teamwork is an important factor when measuring safety climate. The complexity and increased specialization of today's healthcare makes interprofessional teamwork essential for effective and safe management.[96] Discrepancies among professionals' perceptions of teamwork have been shown in the OR,[62 90 97] which may have negative effects on patient safety. This makes it crucial to explore whether diversity exists within the surgical team among other factors related to safety climate. Since leadership is an important factor when establishing a safety culture, it is also important to explore how aware managers are of their staff's attitudes to safety climate.[98] Several studies, using different instruments, have assessed perceptions of patient safety and differences between professionals, managers and units in healthcare.[99 100] However, studies of perceptions of safety climate within the OR are few, [101 102] and comparisons between professionals and between professionals and managers are lacking.

Complex work processes in the OR

Variations, interruptions and disturbances are a common feature during work in a CAS.[43 51] In order to cope with the challenges that may occur in such systems, the ability to adapt and adjust performance to current conditions, often described as resilience, can keep the system sustainable.[43]

Multitasking

Multitasking; that is, managing multiple tasks simultaneously,[103 104] are strategies often used by healthcare professionals to cope with increased work intensity,[105 106] and to prioritize between tasks.[107] However, professionals in the ED did not perceive multitasking as stressful, but instead they considered it as a strategy related to safe and efficient completion of tasks.[108] Multitasking has also been described as a skill and an integral part of daily work, especially in the context of the ED,[105] and notably when exchanging information.[109] It is often seen as an integral part of healthcare. When professionals multitasked, their work processes were affected, which may thereof also have an impact on patient safety.[110 111] Knowledge about multitasking and its impact on patient safety is scarce,[104] and associations have been difficult to establish. However, a recent study on physicians in the ED showed associations between multitasking and increased rates of medication prescription errors.[23] During surgical procedures, professionals in the OR are often available to others through pagers and telephones,[112] which may have the potential for increasing the use of multitasking. Research on multitasking has mostly been performed in the ED, ICU and hospital wards.[106 109 110 113 114]

Interruptions

Compared to multitasking, interruptions are relatively well studied. Nevertheless, they constitute a complex phenomenon, described as a process of a suspending a primary task in order to attend to and work on a secondary one.[115 116] Several interconnected components are involved in interruptions such as equipment and organizational factors, task characteristics and external environment conditions.[117] Interruption as a concept has been interchangeably used in research, and may contribute to challenges in making comparisons between studies.[118 119] Initially, interruptions were mostly studied from a negative perspective, with the main focus on how to prevent them.[119] Recently, an association was found in the ED between interruptions and medication prescription errors.[23] Previous OR studies have shown that interruptions occur frequently,[120 121] and have effects on outcomes including professionals' level of distraction,[120] engagement,[122 123] delay,[121] and interference in the work process.[13] However, interruptions can be of a diverse nature,[117 118] and may also have a positive impact on patient safety; for example, when asking a colleague for advice or when receiving timely information,[124] or patient information.[125] Diverse definitions of communication have also been noted, with most studies describing it from a negative perspective; that is, as the source of an interruption.[126 127] In the OR, communication has been described as irrelevant communication or miscommunication.[13 123 128 129] However, in a CAS, communication is described as crucial to be able to perform supportive interactions for safe and efficient clinical work.[34] This may indicate that interruptions is not well understood in the OR.

Managing complexity

Despite disturbances, sub-cultures, and technological complexities in the OR, most things go well.[41] In a resilient organization, professionals know what to do, what to look for, what to expect, and what has happened. Due to a lack of conceptual clarity, resilience has been operationalized through a theoretical model with four cornerstones: anticipating, monitoring, learning, and responding.[25] Hence, professionals at all levels are the key to creating patient safety and system flexibility.[43] Resilience research has shown that important characteristics for managing complexity include making sense of the situation (sensemaking), making trade-offs between efficiency and thoroughness, anticipation, and adaptation.[46] Adaptation of resilience in inpatient healthcare has been obtained by bridging gaps, proactively monitoring, anticipating and acting on problems and providing staff and patient education.[130] The ability to change coordination activities in response to unexpected events (i.e. adaptive coordination behavior) is another strategy studied in the OR to manage complexity. Behaviors to manage unexpected situations in the OR include task- and information management, teaching and leadership.[131] It is important for the surgical team to know the procedure as well as their own and other team members' roles in performing the procedure. Having the necessary skills is also crucial, such as the resources to perform the tasks and supportive communicative processes allowing adjustments to unexpected events or challenges.[132] The way in which surgical teams manage complexity is not well understood; knowledge of this will be an important contribution in understanding how these teams create safe care in the OR.

RATIONALE

Current theories on patient safety describes healthcare as a complex system (CAS) consisting of several subsystems, with different safety cultures, sub-cultures, and ways of working. This conceptualization of healthcare challenges traditional safety management strategies. To date, the focus on patient safety has predominately been on accidents and errors, and patient safety has often been defined in terms of the lack of safety. However, focusing on what goes wrong does not increase our understanding of why things go well. Recent literature on patient safety does not describe patient safety as a property of a single component; instead, it is viewed as a system property that arises from interactions within the system, for example between team members and organizations. This thesis aims is based on the ambition to understand patient safety from a system perspective, acknowledging the complexity of the healthcare system.

Previous studies describe the OR context as complex, dynamic and with high cognitive demands on staff. The team in the OR face challenges including professional sub-cultures and sometimes lack of support and resources. Previous international research shows that a strong safety climate is associated with lower rates of surgical complications. However, professionals´ and managers´ perceptions of safety climate have not been studied in Swedish ORs. Previous studies of the work processes in the OR have mainly focused on interruptions. Interruptions have mostly been studied from a negative perspective, with the aim of preventing them. Multitasking has been described to have potential effect on professionals´ working memory and have been studied in other healthcare contexts but not in the OR. However, multitasking and interruptions may also have positive impact on patient safety. Managing complexity and understanding how things go well has mostly been studied through concepts such as resilience and adaptive coordination. There is a lack of explorative research addressing what makes things go well in the OR. This thesis contributes with knowledge on how to measure safety climate, how safety climate is perceived by different professional sub-cultures and managers in the OR, how the complex work processes, including interruptions and multitasking, are expressed, and how work is done in the OR. Hence this thesis will, from the perspective of complexity, contribute to the understanding of the next level of patient safety work, with knowledge about how the complexity of the OR is perceived and managed by OR professionals

AIMS

The overall aim of this thesis was to evaluate an instrument for assessing safety climate, to describe and compare perceptions of safety climate, and to explore the complexity of work processes in the operating room. The specific aims of the individual papers are given below.

Specific aims:

Paper I
To establish the reliability and validity of the translated version of the SAQ (OR version) by evaluating its psychometric properties

Paper II
To validate the Swedish Safety Attitudes Questionnaire-operating room (SAQ-OR) version by re-evaluating its psychometric properties for the surgical team

Paper III
To describe and compare attitudes to patient safety among the various professionals in surgical teams in Swedish OR departments. A further aim was to study nurse managers and medical directors´ estimations of their staffs´ attitudes to patient safety in the OR

Paper IV
To describe the type and frequency of tasks, multitasking, interruptions and their causes from a multi-dimensional perspective for the surgical team in the OR

Paper V
To explore how "work is done" as expressed by operating room nurses, registered nurse anesthetists and surgeons, and to investigate how these professionals adapt to create safe care in the OR

METHODS

Study designs

The papers included in the thesis will be referred to by using Roman numbers. A cross-sectional study design, using the questionnaire SAQ-OR was used (I-III). Paper IV was a prospective observational study and Paper V comprised of a qualitative descriptive approach. An overview of included papers is described in Table 2.

Table 2. Overview of papers, designs, samples and data collection methods

Paper	Design	Sample	Data collection
I	Cross-sectional	LPNs, ORNs and RNAs (n=237)	Questionnaire
II	Cross-sectional	Anesthesiologists and surgeons (n=184), LPNs (n=124), and ORNs and RNAs (n=233)	Questionnaire
III	Cross-sectional	Anesthesiologists and surgeons (n=184), LPNs (n=124), ORNs and RNAs (n=233), and medical directors and nurse managers (n=22)	Questionnaire
IV	Observational	Surgical procedures (n=46), ORNs (n=10), RNAs (n=8) and surgeons (n=9)	Structured observations by using a digital tool
V	Interviews	ORNs (n=4), RNAs (n=5), and surgeons (n=8)	Group interviews (n=4)

LNPs, licensed practical nurses; ORNs, operating room nurses; RNAs, registered nurse anesthetists

Settings

Studies included in this thesis were undertaken in the OR departments of different Swedish hospitals. Participating OR departments had different organizational structures; some were multi-specialty ORs that served different surgical specialties, others were organized with specialized OR departments with one anesthesia setting that served a variety of surgical specialties.

Papers I-III

The data were collected at two regional county hospitals and one university hospital (I). In order to include a variety of hospitals and OR departments (II-III), data collection was conducted at one university hospital, one regional county hospital and one local county hospital. All the hospitals were located in different parts of Sweden.

Papers IV-V

The observations and group interviews were performed at one local county hospital (IV-V). However, in Paper V, prior to the group interviews, a pilot interview was conducted with ORNs (n=2) at a county hospital. No revisions of the interview guide were made after the pilot interview. This group interview was also included in the study to increase the number of participants for this specific profession.

Participants

Paper I

In this Paper ORN, RNA and licensed practical nurses (LPN´s) were invited to participate. The inclusion criteria were that they had at least 6 months of working experience from ORs and was on duty during the data collection period.

Papers II-III

All operative members of the surgical team were invited to participate. The inclusion criterion was at least 6 months of working experience in the OR and availability during the data-collection period. The anesthesiologists and surgeons had to be junior or senior physicians in selected surgical specialties. In Paper II-III the ORNs and RNAs were defined as a group (perioperative nurses). A sample size calculation based on a mean difference of 0.5 between groups (3.0 for perioperative nurses and 3.5 for physicians) for safety climate with a significance level of (α) of 5% and a power (β) of 80%,[98 133] showed that a sample size of 134 perioperative nurses and 89 physicians would be required. To allow for internal dropout, assuming a response rate of 60% meant that at least 187 perioperative nurse and 125 physicians had to be recruited. In addition, 124 LPNs were recruited in order to include all professional groups working in the OR; these were not included in the sample size calculation. To assess the reliability and validity of the SAQ, internal consistency and construct validity were evaluated. In total, ten nurse managers and 12 medical directors (managers for both anesthesiologists and surgeons) were eligible for participation and 20 (91%) returned the questionnaire.

Papers IV-V

During the data collection period, 199 procedures in general surgery were performed at the OR department; 46 (23.1%) of these were observed, producing 78 unique observation sessions, including 26 observations per profession. ORNs and RNAs were observed for 66 hours each, and surgeons were observed for 37 hours, with a total time of 169 observation hours.

The group interviews used a convenience sample based on the professionals' availability to be released from clinical work. Informants from three professional groups (ORNs, RNAs and surgeons) with at least six months of employment and working at the OR department were invited to participate. To allow all participants to speak and ensure rich data, the group interviews were divided by profession, and involved and resulted in four ORNs, five RNAs, and eight surgeons (V).

Instruments

The Safety Attitudes Questionnaire

The SAQ was used to measure perceptions of safety climate; that is, patient safety in the OR (I-III).[65] This questionnaire is a refinement of the Intensive Care Unit Management Attitudes Questionnaire.[134] The different versions contain a generic version with the same 30 items, included in the six factors that represents safety climate:[65] *safety climate, teamwork climate, job satisfaction, stress recognition, perceptions of management* and *working conditions* (Table 3). The full version of the SAQ contains 60 items, whereas the SAQ-OR contains 59; of these, 30 belonging to the six factors and the remaining 29 are intended for other research purposes. To allow calculation of mean scores and in accordance with the developer, the answers are based on a 5-point Likert scale from 1=disagree strongly, 2=disagree slightly, 3=neutral, 4=agree slightly and 5=agree strongly. These are then converted to a 100-point scale from 1=0 to 5=100. Answers can be dichotomized by defining a positive score is defined as ≥75 out of 100; that is, the percentage of respondents agreeing slightly or agree strongly for each of the items within a given scale represents the percentage of positive scores. SAQ-OR contains demographic questions covering age, sex, profession, and work experience. Factors and definitions are described in Table 3.

Table 3. Factors and definitions in the Swedish Safety Attitudes Questionnaire-Operating Room version

SAQ factors	Definitions
Safety climate	Perceptions of a strong and proactive organizational environment
Teamwork climate	Perceived quality of collaboration between personnel
Job satisfaction	Positivity about the work experience
Stress recognition	Acknowledgement of how performance is influenced by stressors
Perceptions of management	Approval of managerial action
Working conditions	Perceived quality of the work environment and logistical support (staffing, equipment, etc.) in the operating room

Translation and adaptation of the SAQ (OR version)

The Swedish translation and adaptation of the SAQ-OR followed several steps, according to the guidelines of International Society for Pharmacoeconomics and Outcomes Research guidelines (I).[135] Permission to use the SAQ-OR was obtained in 2010 from the developer of the instrument, Professor J. Bryan Sexton. Forward translation was performed by two researchers whose native language was Swedish and who were proficient in English. Reconciliation of the translations took place between the researchers to seek agreement and resolve discrepancies. To evaluate the face validity, a pretest was carried out with OR professionals (n=6) varying in professional specialty and age. This resulted in some reformulations of items. To achieve semantic equivalence,[136] a back-translation was performed by a professional translator whose native language was English. Conceptual equivalence between the original SAQ-OR and the translation was ensured via a review of the back-translation.[137] Items were rated on a 4-point ordinal consistency scale ranging from 1 (highly consistent) to 4 (not consistent). Of the 59 items in the SAQ-OR, 27 were highly consistent, 27 quite consistent, 5 somewhat consistent and none non-consistent.[136] The research team discussed the two versions, resulting in minor revisions. The back-translation was sent to the developer of the SAQ-OR, followed by a verbal discussion which resulted in two items being excluded from the translated version. Cognitive debriefing, which comprised a validation review, including relevance and intelligibility was performed by an expert committee.[136] Five experts with knowledge concerning the OR context, including one physician, three registered nurses, two PhDs, and one LPN, were recruited. This resulted in some modifications of the translated version of the SAQ-OR. A discussion with the developer resulted in "hospital management" being changed to "unit management" for contextual reasons.

Fatigue, as a concept, was perceived as an overly severe expression and was translated as “being tired”. Proofreading and final quality control were performed by the research team. The full version of the Swedish translation of the SAQ-OR consists of 57 items. The 30 items constituting the six factors representing safety climate were included in the psychometric evaluation. Since Paper I only included perioperative nurses and LPN´s while the data collection for Paper III covered the whole surgical team, the researchers decided that the psychometric properties of the SAQ should be re-evaluated among all professions represented in the surgical team. From the first to the second data collection, minor revisions in item wording was made in 13 of the 30 analyzed items and consider to not influence the reults.

Instrument for nurse managers and medical directors´

To cover nurse managers and medical directors´ estimations of their staff’s perceptions of safety climate were assessed using a short questionnaire derived from the work of Huang (III).[98] For example, the item safety climate was assessed by asking “How do you estimate your staff’s perception of how strong and proactive the OR department’s commitment to patient safety is?” and teamwork climate by asking “How do you estimate your staff’s perception of teamwork climate within the OR where they work?” The six items, based on the six factor definitions, were answered on a rating scale from 1 (worst score) to 10 (best score). All instruments used in the project contained demographic questions covering age, sex, profession, and work experience.

Work Observation Metod By Activity Timing

The Work Observation Method By Activity Timing (WOMBAT) is a tool used in healthcare to capture work complexity.[138] To conduct the observations a portable touchscreen tablet with the WOMBAT software was used to collect multidimensional data on the observations of ORNs, RNAs and surgeons. The tool includes different dimensions of work — *when, what, with whom, how, multitasking,* and *why* (the observable cause of an interruption) — as well as specific categories such as pre-indirect care, intra-indirect care, direct care, medication, documentation, communication, supervision, other, and in transit, plus subcategories within these dimensions. To program the tool, tasks were mapped by exploratory observations of the three professions. The categories and subcategories were then discussed with one expert from each profession. Two of the researchers who carried out the observations discussed the dimensions, categories, subcategories, multitasking, and causes of interruptions in WOMBAT, until consensus was reached. Dummy cases were written and tested to verify that WOMBAT had been correctly programmed. When performing observational studies, a clear statement of the concepts and operational definitions being used is crucial.[118] The concepts used are presented in Table 4 along with their operationalized definitions (IV).

Table 4. Concepts and operational definitions in Paper IV

Concepts	Operational definitions
Multitasking	When a member of the surgical team carried out observable multiple tasks simultaneously e.g. talking to a colleague while preparing medication
Primary task	The ongoing task which is being interrupted
Interruption	When a member of the surgical team suspended a current task because of an observable external stimulus e.g. paused to prepare an infusion when a surgeon asks to change the position of the operating table
Cause of interruption	Describes the cause to an observable interruption
Secondary task	Task that interrupts an ongoing task or tasks
Task after secondary task	Task initiated after secondary task

Inter-rater reliability (IRR) was tested during pilot observations of each profession. After the pilot observations, the researchers discussed, adapted and refined the programming. To ensure reliability of the tool and observer agreement, each of the observing researchers independently shadowed the same profession for 30 minutes. The last three pilot observations showed adequate Cohen's kappa value (≥ 0.81).[139] for the observed tasks: 0.85 for indirect care (pre and intra), 0.87 for direct care, 0.93 for medication, and 0.82 for communication.[140] This required alignment of both observers' independent observations side by side and comparison of tasks by task classification, duration and temporal order. Few interruptions occurred, during the pilot observations, and calculating kappa was not feasible. Identified interruptions, secondary task, and their causes were reported similarly by observers. In addition, IRR was assessed by using the intra-class correlation (ICC) where the proportions of tasks between observers, and proportions of time within task categories were examined.[23] To measure ICC, a two-way mixed model was used. The intra-class correlation was 0.96 (95% CI: 0.83-0.99), indicating a high IRR.

Interview guide

The moderator focused on question areas such as planning and preparing for the day, a context with changes and variations, interruptions, multitasking, organizational aspects, and clarifying questions. The group interviews were conducted between February and April 2018. For the group interviews in Paper V, an interview guide with open questions was conducted and pilot tested on two ORNs. The interview guide consisted of questions such as "Can you tell me how you plan your day at work?", "Could you tell me about situations when the work proceeded according to plan?", "Could you tell me about situations when work did not proceed according to plan?", "What enables and what limits you from being able to do the work as planned?", and "Do you ever have to abandon routines?" There were also demographic questions covering age, sex, profession, and work experience.

Procedures

Paper I

The Swedish version of the SAQ-OR was distributed to the three participating OR departments (A, B, and C) between January and March 2011. The distribution system differed between the three. In two (A and B), a paper version of the questionnaire was distributed to the staff's postboxes. In the OR department (A), anonymous questionnaires were used to protect the respondents' integrity, as one of the researchers worked in this department. In department B, a name and number list was used, and two reminders were sent to those who did not answer. In department C, consisting of eight different operating units, a web-based survey methodology was used for practical reasons. The unit managers emailed the respondents with the questionnaire in an electronic format and information about the study. Three web-based reminders were administered with assistance from the managers.

Papers II-III

The same data collection was used for the re-evaluation of the Swedish version of the SAQ-OR (II) and the cross-evaluation (III). This was conducted between September and November 2014, via a questionnaire with prepaid envelope that was distributed to each employee´s mailbox. To allow reminders for non-respondents, a unique code number was written on each questionnaire. Three reminder rounds were sent. The questionnaire for the nurse managers and medical directors was distributed to their personal postboxes, again with a prepaid envelope.

Papers IV-V

Observations for Paper IV were conducted between November and December 2016. The observations of ORNs and RNAs started when the participants began to plan and prepare for the surgical procedure, and continued until the patient left the OR. The RNAs were also observed in the preparation room, which was near the OR. Observation of the surgeons started when they entered the OR and ended when they left the OR. During the whole surgical procedure, the researcher shadowed the same participant unobtrusively,[141] registering the tasks the participant performed, with whom, how and why (the cause of an interruption). The surgeons were observed for a total of 37 hours, whereas the ORNs and RNAs were observed for 66 hours each, due to the differences in the professionals' start and end times of a surgical procedure.

A qualitative study in which four group interviews were included was conducted (V).[142] All four group interviews were conducted in the same way. Two persons from the research team were present; one as the moderator, who also guided the discussions, and the other as the assistant, who took notes during the sessions. All discussions lasted between 50 and 59 minutes, and were tape-recorded and transcribed verbatim.

Data analysis

An overview of the statistical methods used in Papers I-IV is given in Table 5.

Table 5. Overview of the statistical methods used in Papers I-IV

Method	Paper I	Paper II	Paper III	Paper IV
Cronbach´s alpha	X	X		
Chi-square test		X		
I-CVI	X			
CFI	X	X		
RMSEA	X	X		
SRMR	X	X		
Factor loadings and T values		X		
Polychoric correlation matrix	X	X		
Kruskal-Wallis test			X	
Mann-Whitney U test			X	
Bonferroni correction			X	
Descriptive statistics	X	X	X	X
Confidence interval				X
Cohen´s kappa				X
Intra-class correlation				X

CFI, comparative fit index; I-CVI, item-level content validity index; RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual

Papers I-II

An item-level content validity index (I-CVI) form was developed and used to evaluate the experts' agreements. The experts rated items on a 4-point ordinal scale of relevance and intelligibility, ranging from 1 (not relevant/intelligible) to 4 (highly relevant/intelligible). The I-CVI was calculated by dividing the number of experts that evaluated the item as 3 (quite relevant) or 4 (highly relevant) by the total number of experts. Good content validity is indicated by an ICV-I value ≥ 0.78.[136] The ICV-I for relevance ranged between 0.2 and 1.0, and the intelligibility ranged between 0.4 and 1.0. The cognitive debriefing resulted in nine items that needed to be revised, with ICV-I value <0.78 (I).

To evaluate the psychometric properties for SAQ-OR, internal consistency and construct validity, Cronbach's α values, inter-item correlations, and goodness-of-fit indices were calculated (I-II). Items 12 and 24 were negatively worded, and so were reversed prior to the analysis. To overcome the problem of with incomplete datasets, with data missing completely at random, a multiple imputation was applied in both sets of data. However, this did not substantially change the Cronbach`s α values. The cut-off value of the Cronbach's α for internal consistency was = 0.70,[137] and inter-item correlations within respective factor, correlations >0.30 within each factor were considered to indicate good reliability.[143]

Confirmatory factor analysis (CFA) was used to verify the factor structure of the observed variables (SAQ-OR). This technique allows testing of the hypothesis that a relationship exists between observed variables and their underlying latent constructs.[144] The following measures were used. The *goodness-of-fit statistic* was used how well the defined model fitted the data, and the χ^2 *test* was used to test the close fit of the model. The *standardized root mean square residual (SRMR)*; that is, the square root of the difference between the residuals of the sample covariance and the hypothesized covariance model, was calculated. The *root mean square error of approximation (RMSEA)* was used to measure approximation of the model fit, and the *comparative fit index (CFI)* was used to analyze the model fit by examining the discrepancy between the data and the hypothesized model. *Factor loadings* were calculated to produce a scale showing the relative importance of some collection of items that collectively form a whole. Maximum likelihood was used for estimation. Since the variables consisted of ordinal data, the polychoric correlation matrix of observed variables was applied in the analysis.

Paper III

Although the questionnaire was based on an ordinal scale, in order to allow comparison with previous research the SAQ-OR index was treated as a continuous variable presented in terms of means and SD (III). Calculations of mean values and analysis of variance among the three groups (perioperative nurses, physicians, and LPNs) were computed using the Kruskal-Wallis test. Differences in SAQ-OR factor scores among the three groups were analyzed with the Mann-Whitney U-test with Bonferroni correction to adjust for multiple comparisons. A p-value of <0.05 was considered statistically significant. Nurse managers' and medical directors' estimations were transformed into a 100-point ordinal scale and divided by their staff's actual mean scores for the safety climate on the 100-point scale, by the respective professional groups. Their mean safety climate scores was calculated by taking their estimates of each safety climate factor divided by their staff's actual mean factor scores. A ratio of >1.0 reflected overestimation and <1.0 underestimation.

Paper IV

Descriptive statistics were used to determine the total observation time, number and proportion of tasks, proportion of category-specific task time, and multitasking time based on total observed time per profession and interruption rate per hour of the surgical team (IV). Proportion of task, summation of time on task, proportion of time on task, and confidence intervals (CI) were calculated. In the literature, some have reported a large sample approximation for calculating the CI.[145] Considering the problem of interval estimation of proportion and the erratic behavior of the large sample approximation (the Wald interval), the Wilson's confidence interval was employed. The CI from the Wald interval often has inadequate coverage, particularly for small sample sizes and values of proportions close to 0 or 1, while the Wilson interval is appropriate for both smaller and larger sample sizes and provides more reliable coverage than other alternatives. The Wilson interval uses the estimated standard error instead of the "null standard error".[146] Since the data included both small and large sample sizes and lower and higher proportions, the Wilson's interval was decided to be the most appropriate.

Paper V

Transcribed text from the group interviews was analyzed by focusing on the manifest content and using inductive content analysis according to Elo & Kyngäs.[147] All interviews were transcribed and analyzed separately by professional group (ORNs, RNAs, and surgeons). Meaning units were identified and condensed. Content related to the aim of the study was denoted first in the margins of the text and then on a coding sheet. The codes were sorted into sub-categories on the basis of their similarities and differences, and the sub-categories were then interpreted and aggregated into broader generic categories. The codes were related back to the meaning units several times by the first and last author. One meeting was held with the whole research team where the condensed meaning units and codes from all three groups were discussed. The research team shared critical reflections iteratively during the process, and the sub-categories were discussed, compared, and revised. An example of the analytical procedure is presented in Table 6.

Table 6. Examples of transcriptions, codes, sub-categories and generic categories

Transcription	Code	Sub-category	Generic category
Communicate with the rest of the team so everyone has the same information about what's expected	Communicating with the team so everyone has the same information	Internal communication	Preconditions and resources
Often you know the patient, but if you don't then you read the patient record to get a picture	Often you know the patient, but otherwise you read the patient record and get a picture	Creating a plan for the patient and undergoing mental preparation	Planning and preparing for the expected and unexpected
It's the planning ahead, you plan the surgical procedure. As I said, experience from this or that can happen, but then you have a plan B. Perhaps you also have a plan C as well, as it is like … it's people, and it can't go wrong, you have to handle it	Managing through planning, experience, and having plans B and C	Prioritizing and solving problems	Adapting to the unexpected

ETHICAL CONSIDERATIONS

The research project was guided by the Helsinki Declaration of Ethical principles for medical research involving human subjects guided the research project. The Research Ethics Committee at Dalarna University (2010/891/90) gave an advisory statement for Paper I. The Regional Ethical Review Board in Uppsala, Sweden approved studies underlying for Papers II and III (2014/211) and IV and V (2016/264).

Papers I and II used data from a survey of professionals working at an OR department. To ensure voluntary participation in the study, informed consent was obtained from the participants after providing verbal and written information describing the purpose of the study, the voluntary nature of participation, their ability to withdraw from participation at any time without further explanation, and the fact that answering the survey was considered as consent to participate. The potential harms of observational studies are generally less than those of experimental studies, as no intervention takes place. However, direct observations (Paper IV) may be seen as an intrusion in the participant's daily work life. Three professions were observed in the OR, but there was also one patient, one assisting surgeon, and one LPN present during the procedure. All non-participating staff and patients whose surgical procedures were about to be observed were informed orally about the study and were given the chance to opt out. If any of these opted out prior to or during a surgical procedure, the observation session would end and be excluded from the study. Patients who are to undergo surgery may experience feelings such as vulnerability, and this has to be taken into consideration by researchers. Asking them in this situation might be perceived as slightly unethical, as participants are likely to be in a dependent relationship with both professionals and researchers. However, there were no opt-outs. For the group interviews in Paper V, all participants provided their written consent, were informed that participation was voluntary, and were guaranteed secure data storage. The data for all five papers (I-V) were kept in a locked file cabinet, and the code keys were stored separately from the data. The data were treated with confidentiality throughout, and the results were compiled and reported in such a way that no individuals could be recognized.

RESULTS

The results of the four studies (five papers) on safety climate and complex work processes in the OR are structured and presented together in two sections: *safety climate in the OR* (Papers I-III) and *complex work processes in the OR* (Papers IV-V).

Safety climate in the OR

To understand the contextual challenges, culture, and leadership in the OR, and to identify improvement areas, an evaluation of the psychometric properties and professionals' perceptions of safety climate was conducted using the 30 items in the six factors of the SAQ-OR. Psychometric theory is used to develop understandings of psychological and social phenomena by quantifying them. A total of 374 participants were eligible for participation and 237 (63%) agreed to participate (I). A total of 541 participants were eligible and 332 (61%) consented to participation by answering the questionnaire (II-III). The characteristics of the respondents are shown in Table 7.

Table 7. Characteristics of participants in Papers I-III

Characteristics	Paper I	Papers II-III
Total eligible, n	374	541
Response rate, n (%)	237 (63)	332 (61)
Missing data	7 (3)	-
Profession		
Licensed practical nurses, n	-	124
Response rate, n (%)	40 (-)	74 (60)
Age, mean (SD)	49 (-)	49 (10)
Female, n %	37 (93)	118 (95)
Years of professional experience, mean (SD)	20 (-)	26 (10)
Perioperative nurses[a], n	-	233
Response rate, n (%)	190 (-)	146 (63)
ORNs, n (%)	80 (42)	58 (40)
RNAs, n (%)	110 (58)	88 (60)
Age, mean (SD)	46 (-)	46 (10)
Female, n (%)	167 (88)	117 (80)
Years of professional experience, mean (SD)	20 (-)	20 (11)
Years of specialty experience, mean (SD)	15 (-)	14 (11)
Physicians[b], n	-	184
Response rate, n (%)	-	112 (61)
Anesthesiologists, n	-	40 (36)
Surgeons, n	-	72 (64)
Age, mean (SD)	-	45 (10)
Female, n (%)	-	38 (34)
Years of professional experience, mean (SD)	-	17 (10)
Years of specialty experience, mean (SD)	-	11 (8)

a Perioperative nurses are represented by operating room nurses (ORNs) and registered nurse anesthetists (RNAs)
[b] Physicians are represented by anesthesiologists and surgeons

Psychometric properties of the SAQ-OR

Internal consistency

To ensure internal consistency and homogeneity of the items within the SAQ-OR scale, Cronbach's α values were measured (I-II). The results in both papers showed an acceptable fit within four factors: *safety climate, teamwork climate, job satisfaction* and *stress recognition*, but the other two factors, *perceptions of management* and *working conditions* did not show acceptable fit. In Paper I, the sample included perioperative nurses and LPNs, while Paper II included the whole surgical team: anesthesiologists, LPNs, ORNs, RNAs, and surgeons. The samples in Paper I and II showed similarities in Cronbach's α values, although those in Paper II generally had lower values. *Teamwork climate* and *job satisfaction* had the highest Cronbach's α, except in Paper I where *safety climate* had a higher value.

Perceptions of management and *working conditions* showed the lowest values in both papers (I-II). Comparisons between different professions in Paper II showed that Cronbach's α values were generally lower for the LPNs than for the perioperative nurses and physicians. *Perceptions of management* was the one factor that for all three groups fell below the recommended acceptable α value limit of 0.70 (Table 8).

Table 8. Internal consistency for the factors in the Swedish Safety Attitudes Questionnaire-Operating Room version

	Paper I Cronbach's α	**Paper II Cronbach's α**			
SAQ factors	Total sample (n=237)	Total sample (n=332)	Periop-erative nurses[a] (n=146)	Physicians[b] (n=112)	LPNs (n=74)
Safety climate (7 items)	.83	.75	.78	.82	.68
Teamwork climate (6 items)	.80	.76	.83	.81	.66
Job satisfaction (5 items)	.78	.76	.82	.77	.57
Stress recognition (4 items)	.76	.75	.76	.76	.75
Perceptions of management (4 items)	.63	.51	.46	.58	.49
Working conditions (4 items)	.59	.56	.70	.62	.50

[a] Perioperative nurses are represented by operating room nurses and registered nurse anesthetists
[b] Physicians are represented by anesthesiologists and surgeons
LPN, licensed practical nurse

Internal construct validity

The validity tests of the SAQ-OR in Paper I indicated a good model fit, while the results in Paper II showed an acceptable fit and the factor loadings were significant, which indicates the importance of the item in relation to its respective factor. The goodness-of-fit indices used to evaluate the construct validity for the total sample in Paper I (LPNs and perioperative nurses) and Paper II (LPNs, perioperative nurses and physicians) are given in Table 9. However, in Paper II the p-values, for the total sample and subgroups of perioperative nurses and physicians were <0.001, indicating that the six-factor model did not fit the data exactly and the close fit was rejected. Goodness-of-fit indices and SRMR for total sample in both papers indicated an acceptable fit. Concerning RMSEA and CFI, Paper I showed good fit and Paper II showed acceptable fit. In Paper II, the perioperative nurses' goodness-of-fit indices RMSEA, and CFI showed good fit while the remaining index, SRMR, had an acceptable fit. The physicians' model fit was acceptable according to RMSEA, but the CFI and SRMR values indicated poor fit. Exact values are given in Table 9.

Table 9. Goodness-of-fit indices for the CFA model of the Swedish Safety Attitudes Questionnaire-Operating Room version

	Paper 1	**Paper II**		
Goodness-of-fit indices	Total sample[a] (n=237)	Total sample[a,b] (n=332)	Perioperative nurses[c] (n=146)	Physicians[d] (n=112)
$\chi 2$	-	822.546	534.009	646.630
df, P value	-	390, .000	390, .000	390, .000
SRMR	0.055	0.064	0.067	0.092
RMSEA (90% CI)	0.043	0.062 (0.057 to 0.067)	0.048 (0.037 to 0.059)	0.073 (0.062 to 0.084)
CFI	0.980	0.938	0.975	0.897

SRMR, standardized root mean square residual; RMSEA, root mean square error of approximation; CI, confidence interval; CFI, comparative fit index.
SRMR reference: 0.0 to 1.0, with 0.0 indicating perfect fit, <0.05 = good fit, ≥0.05 and <0.08 = acceptable fit
RMSEA reference: ≤0.05 = good fit, >0.05 and <0.08 = acceptable fit, ≥0.10 = poor fit
CFI reference: >0.95 = good fit, 0.90 to 0.95 = acceptable fit
a Including licensed practical nurses and perioperative nurses = operating room nurses and registered nurse anesthetists
b Including surgeons
c Perioperative nurses = operating room nurses and registered nurse anesthetists
d Physicians = anesthesiologists and surgeons

Investigation of the hypothesized relationships among the factors showed that the correlations ranged from 0.92 to 0.70 (I) and from 0.936 to 0.571 (II). Five of the six factor correlations were significant in both papers (1% level). The *stress recognition* factor had a negative correlation with all other factors (I-II). No significant correlation was found between *stress recognition* and *teamwork climate*, *job satisfaction*, and *perceptions of management*. However, *safety climate* and *working conditions* correlated with *stress recognition* on a 5% significance level (I). *Safety climate* and *perceptions of management* showed no significant correlation with *stress recognition*. Despite one low correlation, *stress recognition* correlated significantly on a level of 5% with *teamwork climate, job satisfaction,* and *working conditions* (II). Correlation matrices are shown in Table 10.

Table 10. Correlation matrix for the factors of the Swedish Safety Attitudes Questionnaire–operating room version

Correlation matrix for the Swedish SAQ-OR factors Paper I

SAQ factors	Safety climate	Teamwork climate	Job satisfaction	Stress recognition	Perceptions of management	Working conditions
Safety climate	1.00					
Teamwork climate	0.88 (6.56***)	1.00				
Job satisfaction	0.70 (5.82***)	0.89 (6.29***)	1.00			
Stress recognition	-0.23 (-2.60**)	-0.08 (-0.93)	-0.03 (-0.36)	1.00		
Perceptions of management	0.78 (6.13***)	0.87 (6.39***)	0.83 (6.09***)	-0.16 (-1.70)	1.00	
Working conditions	0.85 (6.27***)	0.91 (6.40***)	0.89 (6.14***)	-0.23 (2.25**)	0.92 (6.32***)	1.00

Correlation matrix for the Swedish SAQ-OR factors Paper II

SAQ factors	Safety climate	Teamwork climate	Job satisfaction	Stress recognition	Perceptions of management	Working conditions
Safety climate	1.000					
Teamwork climate	0.936***	1.000				
Job satisfaction	0.790***	0.873***	1.000			
Stress recognition	-0.042	-0.149**	-0.148**	1.000		
Perceptions of management	0.849***	0.793***	0.724***	-0.072	1.000	
Working conditions	0.778***	0.880***	0.571***	-0.196**	0.794***	1.000

Values in parentheses for Paper I are T-values
**Indicating 5% significance level
***Indicating 1% significance level

Perceptions of safety climate

The surgical team's perceptions of safety climate

Means scores of perceptions of safety climate among the surgical team were overall positive regarding *job satisfaction* (78.9) and *teamwork climate* (71.7), which represented almost favorable scores. However, *safety climate* (66.2), *working conditions* (66.8), and *stress recognition* (62.9) did not reach positive scores, and *perceptions of management* (57.9) showed even lower scores. SAQ factors with means and SD are shown in Figure 4 for each profession.

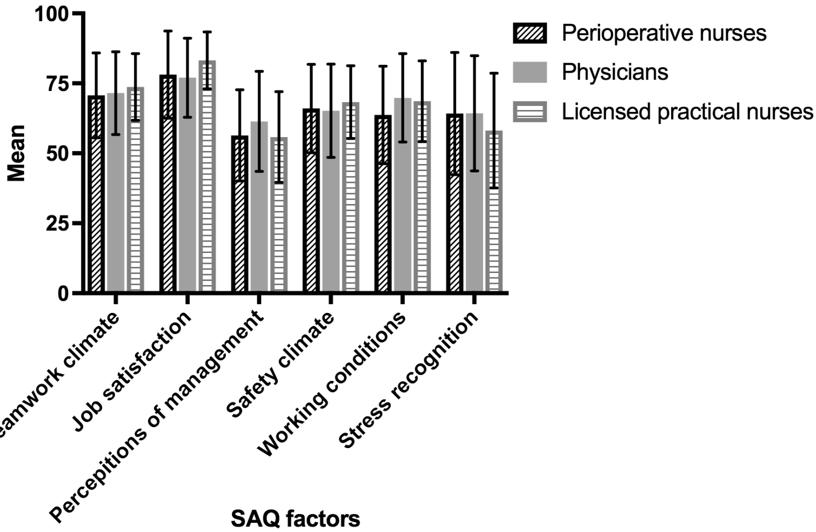

Figure 4. Factors from the Safety Attitudes Questionnaire-Operating Room version with means and SDs for perioperative nurses, physicians, and licensed practical nurses.

Mean percentage positive scores (i.e. ≥75 out of 100 or agree slightly or strongly for each of the items within a given scale) for the six factors were all below 60 % except for job satisfaction.

Comparisons of the SAQ-OR factor scores between the three groups that form the basis of a surgical team (perioperative nurses, physicians, and LPNs). Significantly lower mean scores were shown for perioperative nurses compared to physicians for *working conditions* (p=0.013) and *perceptions of management* (p=0.007) were significantly lower. LPNs scored significantly higher than physicians on *job satisfaction* (p=0.003), but physicians scored significantly higher than LPNs on *perceptions of management* (p=0.016). For *stress recognition*, LPNs scored lower means than both perioperative nurses (0.087) and physicians (0.063), but the differences were not significant.

Nurse managers' and medical directors' estimations

The estimations from nurse managers and medical directors regarding their staff's ratings of safety climate cohered fairly well. However, their mean results were slightly overestimated in comparison to their staff's mean safety climate scores for *stress recognition* (1.13), *safety climate* (1.10), *perceptions of management* (1.07), and *teamwork climate* (1.05). Factors that were slightly underestimated were *job satisfaction* (0.94) and *working conditions* (0.84).

Complex work processes in the OR

Tasks, multitasking and interruptions

As described earlier, the OR setting is a complex and dynamic work environment. To be able to further explore contextual challenges important for patient safety, the complex work processes of the surgical team in the OR were explored. Characteristics of the participants are shown in Table 11 (IV-V).

Table 11. Characteristics of participants in Papers IV-V

Characteristics per profession	Paper IV	Paper V
Eligible ORNs	15	16
Participants, n	10*	4
Observation time, hours	66	-
Age, yrs. mean (range)	46 (26-60)	51.8 (37-61)
Female/male, n	9/1	4/0
Years of specialty experience, mean (range)	13 (2-39)	26.5 (9-38)
Years of hospital experience, mean (range)	10 (0.5-39)	-
Eligible RNAs	16	16
Participants, n	8*	5
Observation time, hours	66	-
Age, yrs. mean (range)	50 (32-64)	59 (49-66)
Female/male, n	3/5	2/3
Years of specialty experience, mean (range)	18 (5-34)	22 (15-36)
Years of hospital experience, mean (range)	14 (5-28)	-
Eligible surgeons	16	18
Participants, n	9*	8
Observation time,hours	37	-
Age, yrs. mean (range)	47 (32-65)	51 (34-67)
Female/male, n	2/7	3/5
Years of specialty experience, mean (range)	13 (0-32)	16 (0-34)
Years of hospital experience, mean (range)	9 (2-28)	-

ORNs, operating room nurses; RNAs, registered nurse anesthetists
* The same ORN was observed 1–7 times, * The same RNA was observed 2–6 times,
* The same surgeon was observed 1–8 times

Four of the 46 surgical procedures were acute and the rest were elective. Regarding type of surgery, 28 of the procedures were laparoscopic and 18 were conducted with open surgery. From incision until wound closure, the procedures lasted between 38 minutes and 3 hours 15 minutes (mean: 42 minutes). General anesthesia was administered in 42 of the 46 (91.3%) procedures and regional anesthesia in four (8.7%).

Tasks and multitasking

From the perspective of the surgical team, on average the team performed 64.4 tasks per hour, with the RNAs performing most (72.0). Proportion of tasks per profession, showed that communication was the most frequent, for surgeons (84.0%, n=1,908), ORNs (50.6%, n=1,948), and RNAs (23.4%, n=1,112). The proportion of category-specific task time (the observed time participants spent performing tasks in a particular category) per total observed time per profession has shown that direct care (equated with surgery) dominating the surgeons' (54.1%, n=100) and ORNs' (33.5%, n=615) intraoperative time. For the RNAs (41.0%, n=1,079), intra-indirect care (i.e. monitoring) took up the largest proportion of category-specific task time. In comparison with the high frequency of communication, category-specific task time for communication (ORNs: 18.0%, RNAs: 8.3%, surgeons: 37.8%), was lower and not as dominant as direct care. Communication was frequent but short, unlike direct care, which was less frequent but ongoing for a longer period of time. Of the total time spent on communication (47 hours and 16 minutes), professional communication represented 81.4% while case-irrelevant communication comprised 18.6% (Table 11).

Due to multitasking, a total of 261 task hours were recorded during the 169 observation hours. Multitasking is the explanation for the discrepancy between observation time and task hours. The observed surgical team spent 48.2% (82 hours 6 minutes, with 173 hours 46 minutes of category-specific multitasking time) of the total observation time multitasking. The proportion that each profession spent multitasking out of their total observed time per profession was 63.1% (42 hours 2 minutes) for RNAs, 53.8% (20 hours 4 minutes) for surgeons, and 30.1% (19 hours 58 minutes) for ORNs. In 74.0% of the observed tasks (n=8,106 out of the total observed tasks n=10,870), the professionals engaged in two and sometimes three simultaneous tasks; for example, supervising a student while monitoring the patient and simultaneously disinfecting their hands. Multitasking was most often observed in ORNs' and surgeons' work during communication (68.8% and 89.0% of the task time, respectively) and supervision (65.9% and 99.9%), while for RNAs multitasking happened mostly during documentation (97.8%) and supervision (89.0%).

Interruptions, causes of interruptions and task after secondary task

The interruption rate for all tasks was 3.0 times per hour (n=511), with the RNAs being interrupted most frequently (4.6 times per hour; n=309, 60.5%). Documentation was the most interrupted primary task, with 3.8 interruptions per hour. Interruptions were also common during intra-indirect care (2.8 per hour, n=181) and direct care (2.1 per hour, n=156). Among all observed causes of interruptions (n=426), equipment-related causes such as malfunctioning equipment, were the most common (n=114, 26.8%), and the second most common were those related to the procedure, for example fog on lens (n=95, 22.3%). The ORNs were mostly interrupted by equipment-related issues (n=48, 50.5%). Medication-related causes of interruptions only affected the RNAs' work (n=46, 18.1%). Procedure-related causes affected the surgeons' work most often (n=35, 45.6%), in addition to equipment-related problems (n=27, 35.1%) (Table 12).

For the surgical team, the most common tasks following secondary tasks were communication (n=150, 39.1%), such as professional communication (n=138, 92.0%). Additionally, the ORNs, RNAs, and surgeons responded to interruptions with intra-indirect care (n=65, 16.9%) or by providing direct care (n=53, 13.8%). Considering communicative responses, the surgeons reacted with n=62 (81.5%), of which professional was n=60 (96.8%), the RNAs responded n=51 (23.8%) of which professional was n=44, (86.3%). The ORNs reactions was n=37 (39.4%) of which professional was n=34 (91.8%).

Table 12. Causes of observed interruptions giving overall frequency and proportion and frequency per hour, for operating room nurses (ORNs), registered nurse anesthetists (RNAs), surgeons*, and the surgical team as a whole

Causes of interruptions	**Examples of causes of interruptions**	**ORNs n (%)**	**RNAs n (%)**	**Surgeons n (%)**	**Total n (%)**
Equipment	Malfunctioning, missing or incorrect equipment Change of OR table	48 (50.5)	39 (15.3)	27 (35.1)	114 (26.8)
Related to procedure	Providing additional information Contaminated sterile area Fog on lens	23 (24.2)	37 (14.6)	35 (45.4)	95 (22.3)
Related to medication	Missing or wrong medication	0	46 (18.1)	0	46 10.8)
Change of shift	Changing staff for break or lunch during the procedure	7 (7.4)	33 (13.0)	0	40 (9.4)
Alarm	Alarm from devices or monitors Indicating high gas pressure	2 (2.1)	31 (12.2)	1 (1.3)	34 (8.0)
External factor	External person entering the room to watch the procedure or to discuss test of new equipment	4 (4.2)	22 (8.7)	4 (5.2)	30 (7.0)
Related to patient	Changing patient position Changes in patient's vital signs	4 (4.2)	20 (7.9)	4 (5.2)	28 (6.6)
Telephone/pager	Searching for surgeons Planning for next procedure	6 (6.3)	16 (6.3)	5 (6.5)	27 (6.3)
Other	Wrong action when assisting	1 (1.1)	10 (3.9)	1 (1.3)	12 (2.8)
Causes of observed interruptions		95 (22.3)	254 (59.6)	77 (18.1)	426 (100)

*Total observation time per profession was 66 hours each for ORNs and RNAs whereas surgeons were observed for 37 hours

Table 13. Generic categories and sub-categories pertaining to operating room nurses (ORNs), registered nurse anesthetists (RNAs), and surgeons, and those shared by the three professions

	Preconditions and resources	Planning and preparing for the expected and unexpected	Adapting to the unexpected
Shared	Communication	Creating a plan for the patient and undergoing mental preparation	Prioritizing and solving upcoming problems
ORNs	Team coordination	Creating a plan for the patient, undergoing mental preparation, and re-evaluating	Prioritizing and solving upcoming problems
	Internal and external communication	Checking and having control	
	Having experience	Taking support from roles and routines	
		Being prepared	
		Planning and adjusting equipment for specific needs	
RNAs	Maintaining focus	Creating a basic plan for work	Prioritizing and solving upcoming problems
	Fast communication	Creating a plan for the patient and undergoing mental preparation	
		Checking	
Surgeons	Having respect for the team and shared goals	Creating a and re-evaluating a basic plan	Prioritizing and solving upcoming problems
	Situational communication	Creating a plan for the patient and undergoing mental preparation	
	Having experience and competence	Using checklists and routines but with ceratin degrees of freedom	
	Maintaining focus and creating space for mental rest		
	Having a positive and flexible approach to change		

Managing complexity

In analyzing the group interviews regarding how the ORNs, RNAs and surgeons perceived the way in which work is done to create safe care in the OR, three generic categories emerged from the sub-categories of each professional group: preconditions and resources, planning and preparing for the expected and unexpected, and adapting to the unexpected (further described together with sub-categories in Table 13). In each generic category, one subcategory was common to the three professions: communication (preconditions and resources), creating a plan for the patient and undergoing mental preparation (planning and preparing for the expected and unexpected), and prioritizing and solving upcoming problems (adapting to the unexpected). Subsequently the generic categories with specific sub-categories representative for each profession follows.

Preconditions and resources

Communication was the sub-category of preconditions and resources that emerged as common to all three professions. When critical situations or changes in patient conditions occurred, communication was considered central for safe care. For the RNAs, an essential precondition was the ability to communicate quickly by having a telephone nearby. For surgeons, communication was a prerequisite for conveying difficult moments during surgery. Communication was perceived as crucial for all team members to have the same information and to create a well-functioning surgical team. The ORNs said that when the team was less integrated there was communication within sub-teams (ORNs and surgeons):

"Communication is more important when the team is not well integrated. That applies to talking to each other, who does what, and what do you need help with, so you don't get parts of the team taking it for granted that others are doing it." (ORN)

Planning and preparing for the expected and unexpected

The three professions said that in order to be mentally prepared they *created a plan for the patient* before the procedure. The ORNs read about the patient, and planned what they might need for that specific patient and procedure. The surgeons said that in most cases they knew the patient, but when this was not the case they created a mental model of the patient and the procedure by consulting the patient record and talk to the patient: as expressed by the quote:

"Often you'll already know the patient, but if you don't then you read the patient record and create a mental picture of them." (Surgeon)

In order to be able to respond to the expected and unexpected, the RNAs said they read the patient record, anticipated what could happen, and created a mental model and plan based on different scenarios which were communicated with the anesthesiologists. To prepare both mentally and practically for the procedure, the RNAs described collecting information, anticipating, and being flexible and responsive to change as important strategies. Clinical experience emerged as a crucial prerequisite to have the ability to plan and prepare for the expected and unexpected. Anticipating changes in patient status intraoperatively was achieved by monitoring trends in the patient's vital parameters. Flexibility and being responsive to signs and signals were inherent abilities, according to the RNAs:

"They want the operating table up and down — it has to be lowered and raised. You have to have radar. That's the way it is, but it's also something that you learn with experience... radar ... you hear." (RNA)

Adapting to the unexpected

Prioritizing and solving upcoming problems was the sub-category concerning adaptation to the unexpected that emerged as common for all three professions. Unexpected urgent procedures were taken care of ad-hoc within the planned work process. The RNAs explained that when facing changes or challenges they adapted to the new situation. To be able to adapt, they used previously created plans B and C, which were a part of their mental model when preparing for the procedure: as expressed by one RNA:

"It's all advance planning, you plan all that and the surgical procedure. As I said, based on experience, this or that may happen, so you have to have a plan B. Maybe a plan C as well. It's human beings we're dealing with — things can't go wrong — we have to handle it." (RNA)

When problems and issues occurred during surgery, the surgeons said that allowing things to go wrong was not an option. Instead, new equipment was used as well as consultation with more experienced colleagues or specialized hospital clinics. The problem had to be solved, and inaction was not an option: as described by the quote:

"If you can't fix the problem with the staff competence you have, you transport the patient. Sometimes we transport patients to another hospital. The problem has to be fixed. Not fixing the problem is not an option." (Surgeon)

Preconditions and resources per profession

ORNs

For the ORNs, *team coordination* and *having experience* were important preconditions and resources for safe care. Familiarity with the team and knowing the capacities of the other members provided security. Cooperating with and supporting less-experienced surgeons and mediating security were described as a significant part of their responsibility. Preconditions for the team were perceived as being focused on the closest team members (surgeons and LPN), the patient, and the assignment, as well as interacting and having a common goal:

"The team — that we feel that together we're doing something good for this patient. The surgery's going smoothly and we have everything we need. You don't have to talk to each other; you just have to know what's going on. You're in phase with each other." (ORN)

Having experience was considered by the ORNs as a resource crucial for maintaining safe care in the OR. Being aware of your limitations and getting a sense of the whole surgical work process was said to become easier with growing experience. Experienced colleagues were also perceived as more aware of the other team members' capacity, competence, and need for support, and experience made it easier to make the decisions, speak up, and follow the plan. Gaining experience could be achieved by reflecting on a situation afterwards and learning from prior situations and decisions.

RNAs

Maintaining focus was specifically described by the RNAs as one of their perceived preconditions and resources. They said that the surgical team has different areas of focus during a surgical procedure. In order to keep focused, the RNAs said they did not let themselves be disturbed, by conveying when disturbances were not appropriate and continuing with the ongoing task as expressed by the following quote:

"When it comes to induction of anesthesia and the awakening, those are the sensitive phases. We can't have people running in and out of the room, giving a lot of information, or asking for a change. That's when there needs to be a little more focus. Those are the situations when we're in an extra sensitive phase, I think." (RNA)

Surgeons

The preconditions and resources described by the surgeons were *having respect for the team and shared goals, having experience and competence, maintaining focus,* and *having a positive and flexible approach to change.* Respect and cooperation were expressed as the most essential preconditions for a well-functioning team and for work in the OR. If the sub-team (e.g. the operating and assisting surgeon and the ORN) was well-functioning, they were less disturbed by what was happening around them. However, when focus was lost in the sub-team, they were more easily disturbed, as expressed in the quote:

"Have an understanding of your colleagues: one team, but in different bell jars." (Surgeon)

Surgeons described that from day one they were trained to handle disturbances, which were perceived as normal and expected. They were prepared for unexpected events to happen suddenly, and knew that they had to handle the situation. These abilities were expressed as being linked to professional experience, which takes time to acquire. High competence in the organization was also described as an important precondition for this ability. The surgeons considered maintaining focus to be an important ability, and several strategies were described. When the level of disturbances and noise was high in the OR, they tried to ignore this by resisting, being calm, and staying in their "bell jar". To leave the focus of the bell jar and handle the disturbance, the reason had to be relevant:

"It's easy to say, but you have to steel yourself and stay hyper-focused. You don't leave that state of extreme focus unless it's something very important and relevant." (Surgeon)

The surgeons described how they took small breaks in order to maintain focus. Working in the OR meant being prepared for a day of change and variation. To handle this, they needed flexibility, adaptability, and the ability to relate to variation and disturbances.

Planning and preparing for the expected and unexpected per profession

ORNs

Preoperatively, the ORNs considered that *checking and having control*, *taking support from roles and routines*, *being prepared*, and *planning and adjusting equipment for specific needs* were crucial in order to ensure safety and security. Several operational checks were described, including functional tests as well as checking settings, the amount of gas, surgical equipment, and the availability of necessary material and equipment. Potential patient risks were checked and communicated to other members of the surgical team. To create a mental model and a shared plan for the surgical procedure, the ORNs read the patient record. When applicable, the marked operating area was checked, and paired organs were double-checked with radiographs and verified with the patient.

To be aware of the patient's condition intraoperatively, the ORNs kept an eye on the anesthesia team, as their activity was an indicator of the patient's status. Another way to ensure safety was counting and checking the sterile instruments and surgical tissues continuously during the procedure. The ORNs said that there were many checklists and tools that supported the work in the OR. They considered that in order to reduce unnecessary interruptions, it was important to follow routines, instructions, and guidelines, and to use checklists, also stated by:

"We have a lot of tools, routines, index cards, positioning guidelines — everyone has their position and knows what to do." (ORN)

In order to be prepared, being one step ahead during the intraoperative process was an important strategy to create safe care. While focusing on the procedure, the ORNs thought about the next step and what might be needed. Planning for the unexpected was handled by being prepared for variation and changes.

RNAs

When planning and preparing for the expected and unexpected, the RNAs *checked* the other team members and which room they were placed in, and *created a basic plan for work*. They also conducted several operational checks prior to surgery, including functional tests, checking of settings, and checking the intended anesthesia equipment: expressed by one RNA:

"Yes, you go through the intubation cart, locate what you need, and bring it out so it's ready — then you can quickly see." (RNA)

Next, they created a tentative plan of what could happen during the day. By looking at the OR schedule for the day, they could anticipate potential changes in the schedule. This was considered important for their mental preparedness.

Surgeons

Planning and preparing for the expected and unexpected from the surgeon's perspective was achieved by *creating and re-evaluating a basic plan* and by *using checklists and routines but with certain degrees of freedom*. The surgeons described how the preparation phase began the day before surgery, when they thought about what was expected and how they would get things done. On the day of surgery, they checked the OR schedule again as it might have been changed. They said it was not feasible to make a rigid long-term plan, as due to the possibility of changes their plan had to be verified and re-evaluated several times during the day. Following routines and guidelines and using checklists was described as important for being prepared, creating a good workflow, and reducing unnecessary disturbances and interruptions during surgery. However, this was declared to be twofold, as sometimes a deviation from routine could be necessary, as expressed by the following quote:

"Routines are built from standard flows. Then you also have urgent situations, but they also have routines, right? So you can know what's coming — at a certain interval this or that will happen and we have routines for it. But in every situation, you also have to be able to improvise. It's like those Russian ice dancers — the more they practice, the more they can improvise." (Surgeon)

DISCUSSION

Synthesis of results

Results shows that in terms of internal consistency on the total sample, the Swedish SAQ-OR showed acceptable fit within the four factors: *safety climate, teamwork climate, job satisfaction,* and *stress recognition*. The other two factors, *working conditions* and *perceptions of management*, did not reach acceptable fit. The goodness-of-fit indices indicated that the six-factor model had acceptable internal construct validity (I-II). The surgical teams' perception of safety climate varied. Aside from *job satisfaction*, the six factors showed low mean percentage positive safety climate scores. When comparing between professional groups, significantly lower mean values were found for perioperative nurses, compared to physicians for *perceptions of management* and *working conditions*. Nurse managers' and medical directors' estimations of their staff's ratings of the safety climate cohered fairly well with their staff's perceptions (III).

The findings show that work in the OR is complex, task-frequent, and multi-dimensional. Communication, including professional communication, was the most frequently performed task, but its duration was short, unlike direct care which was ongoing for a longer period of time. The surgical team multitasked for almost half of their total observation time, mostly while communicating. Equipment-related issues such as malfunction were the most common cause of interruptions. The most frequent task following an interruption was communication between professionals. In order to overcome challenges and create safe care in the OR, the professionals considered that certain preconditions and resources were crucial, including team coordination and having respect for the team, communication, having experience, maintaining focus, and having a positive and flexible approach to change. More specifically, to prepare themselves to respond to expected conditions and adapt to unexpected conditions, the professionals created a mental model of the patient and the procedure by reading the patient record and anticipating risks from different scenarios. When the plan and mental model were established, the team was prepared to respond both mentally and practically in the forthcoming surgical procedure (Papers IV-V).

Discussion of results

Safety culture and safety climate

Complexity means that it could be difficult to assess whether a system is safe or not, as there are inconsistence and no linear relationships between safety culture and patient outcomes. Safety climate is a multifaceted concept, difficult to measure, but nevertheless important to be able to evaluate, and improve. However, an attempt to validate measures that show aspects of safety climate was performed.

Internal consistency of SAQ

In both the sample of perioperative nurses and LPN´s (I) and the sample covering the whole surgical team (II), the SAQ-OR showed good Cronbach´s α values (meeting the recommended limit of >0.70)[148] for the total sample within four of the six factors namely *safety climate, teamwork climate, job satisfaction* and *stress recognition. Perceptions of management* and *working conditions* had low Cronbach´s α score in both papers, indicating poor internal consistency. This is also in line with studies using the SAQ in the OR in other countries.[101 149] The reasons for low α values are unclear. According to the literature, poor interrelatedness between items or heterogeneous constructs and a low number of items included in the factor could influence the results.[150] Missing data, including answers of "not applicable" could also have an impact on the results.[151] The analysis of inter-item correlations (II) for the factors with low α values showed that some items had low correlation with other items. The factors with the lowest scores contained four items, while the others each contained five to seven items. However, the factor *stress recognition* which also contained four items, still had a high α value.

Internal construct validity

The internal construct validity of the SAQ-OR indicated a good model fit in the first sample (I), but when using the extended sample covering the full surgical team the findings showed only an acceptable fit (II). Construct validity of the model was based on CFA and goodness-of-fit indices (SRMR, RMSEA, and CFI), which in line with another SAQ study in the OR[101 149] indicated that SAQ-OR is a valid instrument for measuring safety climate in Swedish ORs. The close fit was also tested by χ^2 *test*, which showed significant *P* values indicating that the six-factor model did not have exact fit, and the close fit was rejected (II). Most other studies have also shown significant findings for χ^2 tests.[91-94 152] Differences between professionals in terms of goodness-of-fit; perioperative nurses had acceptable indices, while among physicians RMSEA was acceptable but the CFI and SRMR had poor fit (II). This is the first SAQ study that in general compares CFA and goodness-of-fit indices between professionals. There were good correlations between latent factors in the SAQ-OR model in five of the six factors. In line with another OR study,[149] *stress recognition* had a negative correlation with all other factors (I-II). The removal of *stress recognition* was tested, but the model did not improve (II). *Stress recognition* is aimed at capturing how stress influences professional's ability to provide safe care and is therefore, compared to the other SAQ factors, related to self-assessment.[93 153] Due to dissonance, some studies have removed *stress recognition* from the SAQ model.[154 155]

Perceptions of safety climate

Teamwork is a significant factor when measuring safety climate. Perceptions of teamwork in the OR have been shown to differ between professional groups. In Sweden[102] and other countries, teamwork was rated good by physicians but mediocre by perioperative nurses.[62 90 97] In line with this, our findings (III) as well as baseline results from another Swedish intervention study,[102] showed variations between professionals' perceptions of the overall safety climate, which is similar to OR studies in other countries.[101 149] Mean scores of *teamwork climate* showed in our study quite high ratings and cohered fairly well between professional groups (III). This is inconsistent with others, and may reflect the degree of diversity of different contexts within a CAS. But also, it may indicate a positive teamwork and increased patient safety awareness in studied OR contexts (III). As in another study from the ICU,[98] and an intervention study in the OR,[102] comparisons between perioperative nurses and physicians, showed significantly lower mean values among perioperative nurses for the factors *working conditions* and *perceptions of management*. Mean percentage positive scores were in our study low (<60%), except for *job satisfaction*, which is in line with studies in ICU contexts.[98 156] Organizations are not cohesive structures with a unidimensional culture; rather, sub-cultures such as workplace cultures arise where professions cluster together and create their own characteristics, albeit influenced by the underlying organizational culture,[157 158] (Figure 2). A possible theoretical explanation for the lack of consistent relationships between safety culture and quality care outcomes[78] could be that the characteristics of a complex and intractable system with existing and evolving professional sub-cultures.

However, our findings are a concern as a weak safety climate has been associated with poor patient outcomes.[72] Improving the safety culture is a leadership task since the organization is adherent to how managers prioritize, understand and implement patient safety.[159] A review of what safety culture is in healthcare, concluded that although creating a safety culture is everyone's concern, this must begin with the chief executive officer and permeate through all organizational levels. Senior managers are crucial for organizational safety.[69] In promoting safety culture, managers have to be aware of how their staff perceive safety climate.[98] One study conducted in ICUs, of Huang and co-workers,[98] showed that managers overestimated their staff´s perceptions, which is not in line with our finding, that the estimations of nurse managers and medical directors cohered fairly well with their staff´s ratings (III). The nurse managers and medical directors in our study were aware that the safety climate was not positive. Leaders need to be engaged and aware of possible variations between professionals and different sub-cultures, their responsibilities, and the potential impact on patient safety. Researchers, have proposed five features that can achieve difficulties in creating and sustaining a safety culture in a CAS. First, patient safety is a "dynamic non-event" that is difficult to visualize; second, patient diseases are complex and manifest differently in different patients; third; the highly specialized nature of healthcare exacerbates the problem of agreement on response to error; fourth, healthcare must contend with interruptions due to missing equipment or supplies, (as confirmed in our study IV) which shifts the focus to temporary workarounds; and finally, a "blame and shame" culture can foster silence even when unsafe conditions appear, which may allow professionals to accept a state of unsafe conditions[159] or lead to normalization of deviance.[160] Some of these features reflect our results and the complexity and difficulty of measuring and improving safety climate.

Safety culture could also be envisioned as the water surrounding a fish. The fish is not aware of swimming in water, but may recognize that it swims in the same direction as other fish. This metaphor could be applied to people who are part of a work culture in a CAS, which is not perceived until it is pointed out.[22 34] Complexity is also claimed to be reinforced by the spectrum of different safety cultures.[7] However, sub-cultures are by no means static;

they are diverse, evolve and adapt in response to changes, for example addition of team members and changing professional constellations and relationships.[161] Despite challenges, it is important to have the intention to establish a strong safety culture in the surgical team, otherwise new and less positive safety culture paths could be established. According to the model of Cook and Rasmussen,[53] the safety culture may begin to move towards the accident boundary (Figure 1). The increasing complexity in healthcare may imply that today´s leaders have to rethink, understand´, and manage the challenges that comes with working in a CAS. This may be aided by using the complexity leadership model,[162] which is characterized by distributed decision making, and strong networking and is supportive of quick and effective adaptations to unexpected conditions.[163] It takes variability, and the needs of staff and patients into account, and involves staff in shared decisions. Given our results, which revealed low and variable scores within the factors for *perceptions of management* and *working conditions* (III), show flaws in leadership which may have impact on patient safety. Some will argue that complexity leadership, may also have the potential to bridge cultural gaps between clinical managers and staff.[164]

Complex work processes in the OR

Several challenges have to be understood and handled to maintain a safety culture in a CAS. Multitasking and interruptions can be viewed as challenges reflecting the complexity of working in a CAS, such as the OR. Several work system factors, such as, person, task, technology, organization, and environment, have been described to have the potential to influence professionals work at different levels.[117] Findings from our study show that professionals perform many tasks, including tasks in parallel (multitasking), and are exposed to different types of interruptions (IV). This implicates a potential effect on professionals´ work processes and working memory as have been described in previous research from the ED and a review of psychological literature.[23 165] However results from the group interviews show that, aside OR professionals, except from the necessity of certain preconditions and resources OR professionals also plan and prepare for the expected and unexpected to manage the complex work processes in the OR (V). Researchers also concluded that, what is described as a complex and stressful environment may instead be characteristics of working in a resilient and adaptive system.[124]

Tasks and multitasking

The number of tasks in the observations (IV) are comparable to what has been found in other complex high-risk contexts such as the ICU. Direct care tasks were less frequent but took up a greater proportion of task time, while communication was the most frequent task, but took up less time (IV). This is in line with findings from other healthcare settings.[21 166 167] The occurrence of communication in the OR may reflect a high degree of connectivity and the need for interaction among professionals to enhance teamwork and a safe, seamless and efficient care process.[96] A study in the ED exploring strategies to manage competing workload demands concluded that communication was crucial to manage workload and provide patient care. The ED professionals also adjusted their communication in response to different contextual factors, such as task type, their experience and location in the ED.[124]

Multitasking in the OR has not previously been studied to any greater extent.[21] According to the observations multitasking occurred during almost half of the professionals´ working time in the OR (IV). From the theory of CAS, multitasking could be interpreted as number of elements that are connected and interact on several levels. In line with studies using WOMBAT in other contexts, as for example surgical and pediatric wards, nuclear medicine, and general wards,[21 167 168] our findings showed that communication was the most dominant task involved when multitasking (IV). This findings from the observations was confirmed in the group interviews, where professionals expressed communication as a precondition and a resource to create safe care in the OR (V). Large amounts of multitasking have been shown in studies using WOMBAT in other contexts, as described above.[21 167 168] However, our results from the OR showed higher scores.[104] Multidisciplinary groups of professionals in settings that require teamwork, such as the OR, may be an explanation for the frequency of multitasking in the OR context. However, it may be more cognitively challenging to handle multitasking in the ED, than in the OR, as the former context includes more expected routine tasks and procedures. Multitasking is of diverse nature and the impact on work performance is limited,[104] which has been described both as a potential threat,[110 111] and as a precondition for safe care.[105 108 109] Recently in the ED, significant associations have been found between increased medication prescribing errors and multitasking and interruptions.[23] Due to modest evidence on the impact of multitasking on work performance, restricting multitasking instead of seeing it as an integral part of the surgical process may create more barriers and increase the complexity of the work process. In a CAS, there is no standard solution to ensure safe care; instead, knowledge-based decisions have to be done in every situation. Researchers have stated that future clinical studies should focus on multitasking behaviors, such as including both concurrent (two or more tasks performed simultaneously) and interleaved (managing multiple tasks and switching between tasks in parallel) multitasking. Clinical studies have mainly investigated concurrent multitasking, without considering the existence of interleaved multitasking.[104] It seems that these complex activities- multitasking and interruptions- are not well understood and include overlaps. They may therefore benefit from being studied as a whole process rather than as single events.[117] Previous work has also shown that multitasking is used to overcome interruptions.[114]

Interruptions, causes of interruptions and task after secondary task

Earlier interruption research has mainly been from a negative perspective with the aim of reducing or preventing interruptions.[119] However, interruptions are a complex phenomenon,[169] and research has shown no clear evidence on negative effects,[170] except from the work of Westbrook and co-workers (as described above) that showed significant associations between increased medication prescribing errors and interruptions and multitasking.[23] In the ED, not all interruptions were perceived as disturbing for the work process,[171] and interruption may even having a positive effect on patient safety.[124 125] As described earlier, interruptions have been studied in the OR,[13 120 121 123 128 172] and communication has mostly been studied and outlined in terms of being the source of an interruption, being irrelevant or being unnecessary. It has even been argued that it is "*a default assumption that interruptions are an inherently undesirable form of communication*" (p.393).[118] Communication was in our study defined and coded as a necessary task (IV),[96] which is in line with the work of others.[124 173] In our group interview study, participants saw communication as a precondition for a safe care process (V). Communication was not seen as a cause of interruptions (IV), but instead the most common interruptions were related to equipment (e.g. lacking or malfunctioning) and to the procedure (e.g. fog on lens). Of all the surgical team professionals, RNAs were interrupted the most and the cause was usually related to medication. This may reflect the characteristics of the different professions and the important function of having an LPN with potential to filter some preventable interruptions, especially for the small team (ORN and surgeon). Our results, showed that the RNAs compared to other professions, were exposed to more multitasking and interruptions and seem to have a more task intense and complex work process. External communication and coordinating tasks, were also conducted by the RNAs. A review concluded that trials to limit interruptions in general medical wards and ICUs are still lacking evidence.[174] This may elucidate the claim that interruptions in a CAS should not be studied mostly from the recipient´s view, but rather from the lens of complexity and from a team perspective. As a CAS contains a lot of interactions within the team, this means that different outcomes may occur for the recipient and the interrupter.[175] One way of understanding clinical work is to describe interruptions in the ED as episodes, and use a three-phase model. interruption start, interruption engagement and interruption end phase. By categorizing an interruption into different phases, the understanding of task behaviors such as multitasking in connection to interruptions could be extended.[176]

Managing complexity

Despite the challenges that may come with working in a CAS, such as the OR, most things go well. According to theory, this is primarily because professionals handle these challenges and accomplish their tasks by adaptations and workarounds.[34] OR professionals plan and prepare both mentally and practically in order to have readiness to adapt and respond to both expected and unexpected conditions. To make sense of different situations, was expressed by the OR professionals as to be dependent on certain *preconditions and resources* such as having experience and communicating. Depending on professional group, communication was explained differently for example as internal, external, fast or situational (V). Communication was frequent also in the observation study (IV), it was frequent, and was used when solving problems or issues through multitasking, while initiating an interruption or solving its cause. In another OR study, communication was seen as important for an open work culture, allowing team members to speak up. Team communication increased when need for coordination and prioritizing between tasks.[131] Communication was a crucial precondition for safe care and a well-functioning team, and was most often used when need for fast internal or external support, or handling of critical situations (V). However, communication is of a diverse nature, sometimes it may cause multitasking (IV), and interruptions, with the potential to affect professionals´ working memory,[17 167] while in other situations it can allow for important transfer of information between professionals,[125] that contributes to a safe, seamless, and efficient care. Individuals´ and teams´ capacity for resilience, can be related not only to one of the four cornerstones within resilience, to respond, ´know what to do´,[25] but also to positive outcomes from adapting to variations and unexpected situations by interaction and communication.[43] Since communication is a necessary precondition of diverse nature that often involves multitasking and interruptions, it should be judged and valued from every situation and with awareness of patient safety.

Another positive impact of team communication is that it allows for greater understanding of risks when sharing plans and mental models,[176] and prevent the team to move beyond the margin of safety (Figure 1).[53] Having shared goals in the team was also expressed as crucial by the surgeons (V). Degree of connectivity is a principle of a CAS which also is reflected by a high degree of communication within the OR-team to manage complexity. All three professions said that in order to be prepared they created a plan and a mental model, for the patient and the procedure (V). They collected relevant information, talked to the patient and anticipated what could happen, which is also another important cornerstone within resilience: ´knowing what to expect´.[25] These behaviors are described in other studies as important for surgical teams in terms of planning,[177] and adaptive coordination.[131] Mental models have also been described as related to effective teamwork,[178] and minimizing uncertain processes with the potential for unsafe care. [179 180] When working in a CAS such as an OR, unpredictability makes it both difficult and important to get a sense of the whole situation. Only guidelines, representing `work-as-imagined´, cannot alone contribute to a comprehensive understanding of work processes. From the study of ´work-as-done´, it seems that mental models,[181] and a common understanding (sensemaking)[182] among the OR team have the ability to enhance *planning and preparing for the expected and unexpected* (V). Retrospective sensemaking is used and triggered when for example the team faces an unexpected situation or lacks information. Sensemaking is dependent on previous experience and performed actions, which also is used when anticipating unexpected situations.[182] Research from the OR suggests that past experiences and knowledge can be useful when anticipating and preparing for situations that may appear. This has been described in the OR as prospective sensemaking,[183] which has the capacity for anticipating expected but undesired situations related to the status of the patient.[25 183] This is also in line with one of our main findings, that in planning and preparing for the expected and unexpected, where the sub-category creating a plan for the patient and undergoing mental preparation (which includes anticipation) was shared among the different professions in the surgical team (V). For managers and those who coordinate daily activities in the OR, it is important to be humble in the face of the complexity the OR team deal with, and create the right preconditions for them to be prepared, by having the ability and time to create plans, make sense, and share these mental models within the team.

The OR professionals described how, in order to *adapt to unexpected* situations and create safe care, they prioritized and solved upcoming problems ad hoc (V). Theorists state that when such a situation occurs, the team have to first notice it, then make sense of it, and then do something about it.[184] This elucidates that sensemaking is involved both when planning and preparing and when adapting to the unexpected (V). In line with other OR studies,[131 177 183] the group interviews (V) also showed that the OR professionals used previously created plans B and C, part of their mental model, to adapt and use resilience to respond to the unexpected.[25] To be prepared with alternative plans, appears to be a common key strategy to handle unexpected events in a CAS. The group interviews (V) may indicate that the planning phase is a crucial pre-requisite for a safe, reflexive and quick response when unexpected situations arise. According to resilience,[24] and in line with other research,[131 185] adaptation is a central key factor for managing the unexpected. It is not always about changing the plan or mental model, but sometimes involves the readiness to modify plans to suit changing situations.[24] However, there is a need for reflection from professionals on the extent of the ability to adapt and the degrees of freedom needed when adapting. Resilience research often describes the extensibility of the system, which may have the potential to push the limits for risks and increase exposure to risk. Despite a positive tone in the literature towards resilience and adaptation, balanced considerations must be made by professionals in order to avoid stretching the limits beyond the margin of safety as exemplified in Figure 1.

Methodological considerations

Strengths and limitations

For psychometric testing, the sample size was lower (I) than the recommendation of ten respondents per item (i.e. 300), for a stable covariation between items.[136] However, the sample size in Paper II was above this recommendation. The response rate was > 60%, which was considered acceptable and the proportion of missing data was relatively small. The response alternative ”not applicable” was also counted as a missing value, as recommended by the developer of the SAQ. When considered alone, the rate of the ”not applicable” response was 3%, with physicians accounting for 68.5 % of these (II). This has not been reported earlier, and may be explained by the fact that physicians belong to other departments, whereas perioperative nurses and LPNs belong to the OR department. Data collection differed somewhat between the hospitals (I), with a web-based survey being used in one hospital for practical reasons. This could be considered a threat to the internal validity of the study. While Paper I included only ORNs, RNAs and LPNs, Paper II included all professionals in the surgical team which can be seen as a strength of the study. However, only six hospitals were included which limits the external validity (I-III). ORNs, RNAs, surgeons and anesthesiologists are different specialties, but they were dichotomized as perioperative nurses and physicians when analyzing the data. This may have limited important variations characterized by the complexity of sub-cultures within professional groups.[34]

To understand how complex work is done, by using WOMBAT as an observation method to provide a multidimensional view of the pre- and intraoperative work process in the OR. WOMBAT is a structured observation tool with operationalized definitions which may reduce the risk of measurement errors. Unlike previous researchers, we also collected data on the causes of interruptions, with concrete examples. Differences between participants in the number of observation hours can be explained by the fact that the preparation time did not include surgeons; this is interpreted as how work is done. The observers had experience of the OR context, which may be seen as both a strength and a limitation. In order to avoid bias, the setting was not familiar to the observers. Another limitation can be seen from the perspective of the surgical team, as only three (ORNs, RNAs, and surgeons) of the six potential professionals were observed. Only one OR setting participated, and the observations did not include night shifts, weekends, or procedures on Fridays, which may limit the representativeness and reduce the generalizability of the findings (IV).

The interviewer in Paper V was an RNA, which may have had both positive and negative effects on the findings. While context-specific nuances may have been easier to understand, many things could have been taken for granted. Variation in gender, age, and experience was achieved. Mean age and experience were both quite high within all participating groups, presumably due to low staff turnover. This can be interpreted as both a strength and a limitation, as participants with a lot of experience may contribute richer descriptions than those with less experience, but on the other hand, less experienced participants may have contributed more variation in the phenomena under study. Trustworthiness[186] in terms of confirmability was ensured by presenting transcripts, codes, sub-categories, and generic categories. Interactive discussions took place among the researchers, and quotations were presented in connection with descriptions in order to ensure credibility. Triangulation of sources was performed by comparing descriptions of the same phenomena from the three professions. Independent categorization ensured that analyst triangulation was achieved. The observations and interviews were conducted at the same OR department, participants could both have been interviewed and observed which is a strength of the study.

Clinical implications

From a system perspective, safety management of a CAS presents a great challenge in terms of that the system is constantly changing. Other considerable challenges in Sweden include an aging population, co-morbidities, human resource constraints and reduction of patient beds. The OR context includes challenges such as uncertainty stemming from variations, the surgical procedure in itself which sometimes is performed under time pressure, patients with complex diseases and the work process is a subject to demands for increased efficiency and production pressure. Despite these challenges a lot of things go well much due to the adaptability of professionals in the OR. Except from standard operating procedures, and to be able to handle the challenges of today´s healthcare, not only professionals have to be adaptable but also managers. Being adaptable could be described as the ability for the system to act in both a structured and flexible way, which could be achieved by networking and building an environment that supports interactions. Creating a capability for self-organizing is important, as these systems cannot be controlled with a traditional top-down steering. Since there is constant change in these systems, monitoring of activities and boundaries seems important for being able to respond to both expected and unexpected conditions. Rasmussen´s dynamic safety model"[53] could be used to illustrate and identify the system boundaries and the safe operating zone (Figure 1).

For those who are responsible for planning and organizing healthcare, some findings and reflections in this thesis will be useful. To maintain focus on the right things, patient safety work has to have a system perspective, which could benefit from applying complexity theory as a lens. Patient safety has to be defined also by what it is, and not only by its opposite, namely lack of safety. In order to gain an understanding of complexity, managers who may have previously assumed, that work can be prescribed in detail (i.e. how work should be done, or work-as-imagined), should become aware of how their decisions and actions corresponds to what actually happens, work-as-done. Work-as-imagined is often an idealized view of how work is done. To bridge the gaps between levels in healthcare, managers have to be more aware of and able to adjust to the fact, that healthcare is a CAS with constantly changing conditions, and in which professionals meet and mostly, but not always, manage daily work. All managers should actively engage in questions of patient safety which have to be communicated through all organizational levels. This could be achieved by patient safety leadership walk rounds, which have shown a positive impact on raising mutual awareness of safety culture. This will have the potential to promote a positive safety culture, that permeates all levels in the healthcare system. Variations in perceptions of safety climate between different professional sub-cultures may have an impact of teamwork and patient safety. Improvements, should be considered within all organizational levels. Applying a complexity leadership approach, characterized by strong networking and distributed decision making may bridge cultural gaps between clinical managers and staff. Interventions or improvements should be evaluated by assessing the safety climate using SAQ.

On a unit-level in the OR, awareness and respect have to be acknowledged for the complex work processes that include multiple and sometimes difficult tasks, multitasking, and interruptions. Interruptions can be perceived as positive, neutral, or negative for patient safety. Since the knowledge around multitasking and interruptions in clinical work is not clear and not well understood, implementing more barriers, may entail increased complexity. Work processes have to be treated with caution. In order to filter unnecessary interruptions, professionals could be instructed to assess whether their issue is really necessary before interrupting a colleague in the middle of something. Specific moments which are sensitive to interruptions, could be identified and treated with caution. When necessary, multitasking and interruptions should be accepted and allowed but with awareness of patient safety.

The improvement of safety culture by adaptive capacities such as anticipating and monitoring creates the ability to respond to the expected and unexpected. Before a procedure starts clinical managers and surgical teams should use briefings to discuss potential risks and solve problems. In order to promote learning and to have the same goals, mental models, should be shared and discussed between members of the team. After the surgical procedure, debriefings about what and why things went right and what could be improved could support reflective learning. The high occurrence of equipment related interruptions may indicate the importance of having support functions that can provide operational checks. Intraoperatively, the LPN seems to have an important support function in terms of filtering preventable interruptions, especially for the small team (ORN and surgeon).

Future studies

From a system perspective, since the OR is a technology tight context, future research on safety culture should focus on extending the safety climate factors with technological aspects important for patient safety. Further research in the OR should focus on understanding complexity, by looking at potential contextual challenges. Multitasking and interruptions in clinical work could benefit from being studied as a whole process, not as single events. Using WOMBAT for data-collection may contribute to making this possible by linking social network analysis with the process of tasks, multitasking, and interruptions. Furthermore, observations with WOMBAT complemented with the think-aloud technique could contribute more understanding of how complex work in the OR is done, which cognitive artifacts are needed, and how these artifacts can be aquired. WOMBAT is modifiable and therefore could also be adapted and tested in other healthcare settings.

CONCLUSIONS

The evaluation of the psychometric properties of the SAQ-OR indicates that it is a reasonably reliable and acceptably valid instrument for assessing perceptions of safety climate among the surgical team in Swedish ORs. Perceptions of safety climate in the OR vary between professionals. According to percentage positive scores, the weakest areas are teamwork climate, safety climate, perceptions of management, working conditions, and stress recognition, all of which are fairly well acknowledged by nurse managers and medical directors. Working in an OR is complex, and consists of multiple tasks with professional communication being the most common. The professionals constantly dealt with multitasking and interruptions which were mostly followed by communication, reflecting the need for interaction and adaptation in a CAS. Managing complexity and creating safe care when working in the OR was described as a process of planning and preparing for the expected and being ready to adapt to the unexpected. Overall, the findings illustrate a dynamic and variable process in a complex system with a safety culture containing variations in perceptions of safety climate among professional sub-cultures, which may have an impact on the prerequisites for creating safe care. The work processes are challenging and complex, but by having certain preconditions and resources OR professionals anticipate and create mental models to be able to handle expected situations and adapt to unexpected events.

SVENSK SAMMANFATTNING

Avhandlingens fokusområden är indelade i två områden: säkerhetsklimat respektive komplexa arbetsprocesser inom operationssjukvård.

Operationssjukvård är ett exempel på ett komplext system och en utmanande och dynamisk miljö. Utmaningar är till exempel patienter med komplex sjukdomsbakgrund samt begränsningar av arbetet i form av tid och resurser. Att genomföra ett kirurgiskt ingrepp är komplext och kräver att olika professioner (undersköterskor, sjuksköterskor och läkare) i teamet besitter både tekniska- och kognitiva färdigheter, interagerar och samarbetar. Operationsteamet behöver även förutse en patients behov, övervaka, hantera förändringar och oförutsedda händelser. Förutom detta har varje enskild organisation sin säkerhetskultur med olika professionella sub-kulturer vilka kan påverka hur arbete och teamarbetet utförs på en operationsavdelning. I säkerhetskritiska organisationer såsom kärnkrafts-industrin och hälso- och sjukvården är säkerhetskultur en viktig del i styrningen av en organisation. En positiv säkerhetskultur anses även ha betydelse för patientsäkerhet.

Tidigare internationell forskning inom operationssjukvård har visat ett samband mellan starkt säkerhetsklimat och minskad andel kirurgiska komplikationer. För att mäta säkerhetsklimat finns olika frågeformulär. När detta avhandlingsarbete planerades saknades sådana instrument anpassade för en svensk kontext. Vidare har internationella studier visat att det finns skillnader mellan olika professioners uppfattning av teamarbete inom operationssjukvård. Teamarbete är en viktig faktor i säkerhetsklimat och studier inom operationssjukvård saknades internationellt. Skillnader mellan hur chefer skattade att deras personal uppfattar säkerhetsklimatet fanns beskrivet internationellt men saknades för svenska förhållanden. Syftet var därför att översätta, anpassa och testa frågeformuläret Safety Attitudes Questionnaire-operating room (SAQ-OR) version för att sedan beskriva och jämföra olika professioners uppfattningar om säkerhetsklimat inom svensk operationssjukvård samt beskriva respektive chefers skattningar av hur de trodde att deras personal uppfattade säkerhets-klimatet.

I operationssjukvård utsätts vårdpersonal ofta för utmaningar såsom variationer, multitasking (utföra två eller flera uppgifter samtidigt) samt avbrott. Detta kan medföra brister i informationsöverföring genom att arbetsuppgifter glöms bort och inte slutförs. Studier har även visat att multitasking och avbrott kan ha en positiv betydelse för arbetsprocessen. Inom operationssjukvård har frekvens, duration, utfall och källor till avbrott studerats. Kommunikation mellan personal har i flera studier inom exempelvis akutmottagningsvård och vårdavdelningar visat sig bidra till avbrott. Men då kommunikation kan ses som en del i arbetsprocessen för att lösa problem är ofta grundorsaken något annat, såsom problem med medicin-teknisk utrustning. Inom svensk operationssjukvård är det sparsamt med studier av avbrott. Internationellt har inte multitasking studerats inom operationssjukvård. Syftet med detta projekt var därför att beskriva typ och frekvens av arbetsuppgifter, multitasking, samt avbrott inom operationssjukvård.

Trots alla utmaningar som beskrivs ovan går mycket av arbetet inom hälso- och sjukvården bra. För att hantera en utmanande miljö beskriver resilience engineering på ett teoretiskt plan, hur människor gör och hur deras förmåga kan stärkas genom att acceptera och hantera komplexa situationer istället för att fokusera på det som går fel. Explorativa studier som undersöker hur operationspersonal gör för att hantera komplexitet och skapa säker vård är dock begränsade. Denna avhandling bidrar till en ökad förståelse för den komplexa miljön inom operationssjukvård, innefattande olika sub-kulturer och komplexa arbetsprocesser, för personal samt hur komplexitet hanteras. Avhandlingens övergripande syfte var därför att utvärdera ett frågeformulär för att bedöma säkerhetsklimat, beskriva och jämföra uppfattningar om säkerhetsklimat och undersöka komplexitet i arbetsprocesserna inom operationssjukvård.

I delarbete I översattes och testades frågeformuläret SAQ-OR, innehållande sex faktorer, säkerhetsklimat, teamsamarbete, arbetstillfredsställelse, stressmedvetenhet, uppfattning om ledning och arbetsförhållanden, och testades för reliabilitet och validitet på sjuksköterskor och undersköterskor (n=237). I delarbete II re-evaluerades SAQ-OR mot hela operationsteamet (operationssjuksköterskor, anestesisjuksköterskor, undersköterskor, anestesiologer och kirurger) (n=541). Resultatet visade att SAQ-OR är ett relativt tillförlitligt och acceptabelt instrument som kan användas för att bedöma uppfattningar om säkerhetsklimat inom svensk operationssjukvård (I, II).

I delarbete III, med samma urval som delarbete II, undersöktes operationsteamets uppfattning av säkerhetsklimatet på tre operationsavdelningar i Sverige (n=541), genom frågeformuläret SAQ-OR. För att undersöka chefernas (n=22) skattning av hur de trodde att respektive personalgrupp uppfattade säkerhetsklimatet på operationsavdelningen användes ett kort frågeformulär med de sex faktorerna som ingår i SAQ-OR. Resultatet visade att operationsteamet trivs på arbetet medan de andra faktorerna skattades något lägre samt att det fanns en variation mellan olika professioner. I jämförelse mellan perioperativa sjuksköterskor (anestesi- och operationssjuksköterskor) och läkare (kirurger och anestesiläkare) skattade sjuksköterskor "arbetsförhållanden" signifikant lägre än läkarna. "Uppfattning om ledning" var signifikant lägre hos både perioperativa sjuksköterskor och undersköterskor än hos läkarna. Chefernas skattning var relativt samstämmig med personalens uppfattning av säkerhetsklimatet.

För att studera arbetsprocesserna inom operationssjukvård observerades operationssjuksköterskor (n=10), anestesisjuksköterskor (n=8) och kirurgers (n=9) arbetsuppgifter, multitasking och avbrott (IV). Observationerna visade på flera utmaningar i form av multipla arbetsuppgifter, där professionell kommunikation var den vanligast förekommande i absoluta tal men i förhållande till tid var det direkt vård (kirurgiska ingreppet). Under nästan hälften av arbetsuppgifterna utfördes även multitasking d.v.s. personalen utförde flera arbetsuppgifter samtidigt. Personalen blev också avbruten under pågående arbete, där den vanligaste orsaken relaterades till medicin-teknisk utrustning, och avbrotten följdes vanligtvis av professionell kommunikation.

I delarbete V utfördes tre gruppintervjuer, två grupper med operationssjuksköterskor intervjuades vid två separata tillfällen (n=4), samt anestesisjuksköterskor (n=5) och kirurger (n=8) verksamma inom operationssjukvård, vid ett tillfälle för att beskriva hur personal gör och anpassar sig för att skapa säker vård. För att skapa säker vård och hantera ett kirurgiskt ingrepp i en utmanande miljö som operationssjukvård beskrev personalen en process där en mental modell, eller karta, skapas genom att de förutser och planerar både för patient och kirurgiskt ingrepp. En mental modell medförde, mental och praktisk förberedelse, samt att de hade kapacitet att kunna svara och hantera både förutsedda och oförutsedda händelser. För att kunna skapa en modell att använda i olika situationer beskrev personalen att det krävdes olika förutsättningar och resurser såsom teamsamarbete, kommunikation och erfarenhet.

Slutsatsen är att SAQ-OR är ett relativt tillförlitligt och acceptabelt instrument som kan användas för att bedöma uppfattningar om säkerhetsklimat inom svensk operationssjukvård. Uppfattningen av säkerhetsklimat visade på variationer och vissa svaga områden vilka även överensstämde med avdelnings- och verksamhetschefernas skattning. Att arbeta inom operationssjukvård är komplext och består av multipla arbetsuppgifter där professionell kommunikation var den vanligaste. Personalen hanterade ständigt multitasking och avbrott, vilka mestadels efterföljdes av kommunikation. Detta speglar de interaktioner och anpassningar som är vanliga i ett komplext adaptivt system. Att hantera komplexitet och skapa säker vård inom operationssjukvård beskrivs som en process av planering och förberedelse för det förväntade och beredskap för att kunna anpassa sig till det oväntade.

Sammanfattningsvis illustrerar resultaten operationssjukvård som ett komplext system med en dynamisk och föränderlig verksamhet med en specifik säkerhetskultur bestående av olika sub-kulturer vilket kan påverka förutsättningarna att skapa säker vård. Arbetsprocesserna är utmanande och komplexa men genom att ha rätt förutsättningar och resurser förutser och skapar personalen mentala modeller för att kunna hantera förutsedda händelser och anpassa sig till oförutsedda händelser.

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