Virtual simulations for training collaborative practitioners at the hospital

Master's Thesis in Computer Science

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Abstract

The management at the department of neurology at Østfold Hospital Trust (ØHT) want to optimize the thrombosis procedure, i.e. the treatment of patient experiencing clogged veins and arteries, which may lead to strokes and heart attacks.

Through an ongoing collaboration between the hospital and the virtualization company Attensi, a prototype of a realistic virtual simulation mediating the standard operating procedure, has been developed. The department management want this simulation to function as a training tool for the practitioners working with thrombosis treatment, reducing the treatment time of incoming patients with presumed thrombosis.

By using theories and insights from Computer Supported Collaborative Work (CSCW) and practice theory, I have inquired into how a prototype of a virtual simulation represents the work as performed by the teams responsible for this treatment. To understand how this technology can support collaborative work at the hospital, I have used well known concepts from CSCW and practice theory, including awareness, articulation work, situated and contingent action, planning and practice.

Performing field observations, I have studied thrombosis treatment and simulated training as performed by practitioners in the hospital's computed tomography (CT) scan room. I have conducted interviews with hospital management, practitioners, and developers at Attensi. Further, user testing of the prototype were performed, shedding light on how the prototype was received by the workers involved with the treatment.

The three main findings from this study are:

1. The thrombosis procedure is highly situated and interdependent, and therefore requires complex decision making and collaborative skills, which practitioner at the hospital mainly learn by participating in the procedure.

2. Virtually simulating the complexity of a real life emergency procedure is challenging, as developers must find a balance between supporting formal work descriptions and informal practices.

3. The current prototype is perceived as too rigid, not representing the situated work as practiced by the thrombosis treatment team.

The findings from this study shed light on various implications for design, including how the development and implementation of randomized scenarios could make the virtual simulation function as a beneficial training application for collaborative work, and could further support the situated nature of a thrombosis procedure.

Keywords: Virtual simulation, task trainer, CSCW, articulation work, clinical practice, practice communities and learning

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Chapter 1

Introduction

The health sector calls for constant improvements of medical procedures and optimization of technological systems supporting the practitioners performing medical work. These workers need advanced assessment and training methods that support the performance of routines and collaboration at the hospital. Health practitioners are in the need of better techniques to uphold patient safety, and methods to gain collective knowledge about collaborative routines across professional boundaries. This have for a long time motivated the development of information systems for clinical care-giving.

At Østfold Hospital Trust (ØHT), the survival rate of incoming patients diagnosed with thrombosis is significantly low when compared to national numbers. Thrombosis refers to the blocking of the blood circulation due to the formation of blood clots in the body's large arteries (Office of the Surgeon General (US and others), 2008). If portions of these clots break loose, they can cause life-threatening complications as they travel to the heart and the lungs via the blood stream, partially or completely blocking the pulmonary artery (the artery carrying blood from the heart to the lungs for oxygenation). The management at the department of neurology have therefore focused on optimizing the process steps of the thrombosis, reducing the treatment time of each patient.

Further, due to the current high turnover of practitioners at the department, the teams responsible for performing thrombosis treatment often consist of workers without sufficient knowledge of the procedure. Today, the practitioners obtain knowledge of the treatment during formal education, simulation training in the CT scan room, and observation and participation in real thrombosis procedures.

In the ongoing collaboration between ØHT and the virtualization company Attensi, they are currently investigating how a virtual task trainer can be used as a training tool by the practitioners involved with the procedure, generating experience about the treatment of incoming patients with presumed thrombosis. In medical training, task trainers are devices designed to train personnel in key activities of clinical procedures (Simonson, 2017). ØHT and Attensi want to develop a realistic *virtual simulation*, hoping that through use, the practitioners will gain further knowledge of routines, resulting in decreased treatment time of patients with presumed thrombosis. The term virtual simulation, or virtual environment, describes an immersive, computer-based simulation that enhance or simplify reality, where users are represented by digital avatars, interact with agents and artifacts in a three-dimensional model-based environment (Dawley and Dede, 2014). I will henceforth use the abbreviation for virtual simulation, VS, when describing these systems.

Attensi has developed a prototype of an interactive and realistic VS. Using features from video games, this simulation mediates the work descriptions of the team leader in a thrombosis procedure. Often referred to by using the term *gamification*, these video game features include point scoring and time tracking, meaning to increase experience and engagement in non-gaming contexts (Deterding et al., 2011).

Using a VS as a training method at the hospital makes it possible to practice clinical work without endangering a patient. Previous research have found computer-based simulations to be adequate training tools, enabling collaboration and decision-making through the use of problem-based scenarios, allowing participants to construct personal and technical skills through interaction with the virtual environment (Ghanbarzadeh et al., 2014).

VSs are therefore used as training applications for emergency management and flight control. Scientific findings regarding VS applications as training tools for collaborative work settings are however scarce within the research field of *Computer Supported Collaborative Work* (CSCW). As an interdisciplinary research field, CSCW is concerned with computer technologies which purpose is to support collaborative work arrangements (Schmidt and Bannon, 1992). Although various studies related to the research field *Computer Supported Collaborative Learning* (CSCL) have established games as beneficial collaborative learning environments in education (Zea et al., 2009; Echeverría et al., 2016), I have found little research regarding VS as tools for training collaborative, clinical teams by simulating complex workplace environments.

This thesis are inquiring about how the prototype of the VS created by Attensi supports collaborative, clinical practice, and how it can function as an adequate task trainer for the practitioners. I have used concepts from the research field of CSCW to gain a deeper understanding of the requirements for the development of VSs, and how simulations can be integrated into the hospital as a tool for collaborative training. I have used concepts like articulation work and coordination mechanisms to understand how workers collaborate to reach a collective goal in a highly situated environment, and how the VS represents this collaborative practice. According to Schmidt and Bannon (1992), articulation work can be described as a set of necessary activities which purpose is to manage the distributed and *situated* nature of collaborative work (Schmidt and Bannon, 1992). Articulation work is understood as a secondary work process essential for collaborative work as it coordinate, allocate, schedules and divides tasks and processes between co-workers. They further explain how people, in order to reduce the complexity of the collaborative work, applies different coordination mechanisms, e.g. plans, schedules and standard operating procedures. Recognising how VSs can work as training tools in collaborative workplaces may introduce an understanding of how work in emergency and safety critical sectors can be supported using simulation technology.

Further, practice and learning theories may give insights into the potential of VSs as training applications. Theories of practice and learning are, among other things, concerned with how individuals learn to understand practices by progressively engaging in the work (Gherardi and Nicolini, 2002). According to Lave and Wenger (1998), working individuals become involved with *communities of practice*, which are made up of individuals engaging in a collaborative pursuit to make sense of and learn about the world, be it formal professions or informal social groups (Lave and Wenger, 1998). Further, they are concerned with how individuals learn through participation in collective activities, trying to place learning not as an acquisition of certain forms of knowledge, but in "situations of co-participation" (ibid, p. 3). Here, workers construct an identity in relation to the participation in the community. Further, participants learn required skills regarding e.g.

their line of work, and they are learning it in the proper context of that work. Gherardi and Nicolini (2002) further explain how practices sometimes are shared across several communities, creating a network of closely interconnected communities of practice. In the hospital, this constellation are seen as representatives from different professions (e.g. senior doctor, residents, nurses and radiologists) are closely collaborating in the treatment of thrombosis, with both shared and not shared practices.

Also, using concepts from theories of awareness, I have tried to understand how 1) collaborating individuals makes sense of unfolding situations in the CT scan room at the hospital, and 2) how this sense making are supported in the VS. Heath et al. (2002) explain the concept of awareness as an underlying activity each member of an organisational environment must engage in in order to partake in complex, cooperative activities with fellow practitioners (Heath et al., 2002). They describe awareness as a "feature of practical action" rather than a 'state of mind' or a 'cognitive ability', and is concerned with concepts such as mutual awareness between co-present workers or displaying availability in shared, virtual environments (ibid, p. 2).

The VS has potential to act as a task trainer, teaching collaborative practitioners in the hospital about the performance of thrombosis treatment. Therefore, I prone the following research questions:

RQ1: How, according to clinical practitioners, do a prototype of a virtually simulated task trainer, mainly developed using a standardized procedure plan, represent thrombosis treatment as practised by teams responsible for this treatment at ØHT?

RQ2: How do an evaluation of this prototype and clinical practices shed light on realistic virtual simulations for supporting 1) the training of practitioners and 2) ongoing articulation work within clinical teams?

The methods used for answering the research questions included reviewing related works, where I have made inquiries about virtual task trainers and computer supported training mechanisms both in and outside the health sector.

I have investigated how the prototype was received by clinical practitioners through user testing, observations and interviews. Interviews with management at ØHT have resulted in a deeper understanding of the need for a task trainer as seen from an administrative perspective. Interviews with developers at Attensi gave insight to the process of developing the virtual simulation in respect to both the standardized procedure and clinical practice. Further, I have performed field studies, where on-site observations and informal conversations with practitioners gave insight to the community of practice involved with the emergency treatment, and how they perform collaborative tasks when treating patient with presumed thrombosis. Also, observations of thrombosis simulation training have shed light on the current training method at the hospital.

1.1 Review of related work

Health services and clinical institutions around the world have seen increased investment in simulated clinical tools, like mannequin simulations, technological task trainers and virtual simulations (Nestel et al., 2017). Mannequin simulations are partial or full-size human-like simulations representing patients for healthcare education (Palaganas et al., 2014). Virtualization applications are regarded as suitable for training practitioners within clinical sectors (Nestel et al., 2017), and are found to present several beneficial and innovating ways of improving clinical care and other health-related activities (Ghanbarzadeh et al., 2014). According to Ghanbarzadeh et al. (2014), previous research have mainly focused on nursing (e.g. public health service, patient safety simulations, disaster scenarios), emergency (trauma management, speed and accuracy of nurse response) and medical education (virtual patient simulation) (Ghanbarzadeh et al., 2014). VSs are currently used in other domains, like retail, marketing and more relevant areas like disaster response and procedure training. When it comes to guidelines for simulation design, development and implementation, there are however no explicit agreed upon conventions, only a range of diverse propositions (Nestel et al., 2017).

Nonetheless, VS applications are considered promising tools for promoting communication and coordination, and for the development of critical skills required in various medical situations, like in the operating room where different professionals must perform and respond in close collaboration (Nestel et al., 2017; Stokowski, 2013; Creutzfeldt et al., 2010; Graafland and Schijven, 2013; Correia et al., 2016; Prasolova-Førland and Divitini, 2003).

According to Nestel et al. (2017), computer-based clinical environments offer a range of beneficial attributes, like immersion, presence, and engagement, and acts as a safe 'play space' for team-based activities (ibid). Compared to custom healthcare game developments, VSs are a relatively low-cost approach to training. Due to these specific attributes, they further explain that VSs yield authentic, relevant and suitable experiences for training on collaborative activities in healthcare.

By using terms developed to understand video games, we can describe a virtual simulated environment as equivalent to a single-player game, where each individual user explores an asynchronous virtual world. A VS can also be constructed as a multi-player application, where different participants explore the VS in a shared, synchronous, three-dimensional environment. These are called *collaborative virtual environments*, and are shared by participants across a computer network, where each participant are represented by an avatar which in some form mediates information about the player (e.g. identity, presence, location and activity) (Benford et al., 2001).

1.1.1 Supporting learning, practice and management of contingencies

According to Ghanbarzadeh et al. (2014), VSs have been used as beneficial tools in professional training (Ghanbarzadeh et al., 2014). A variety of studies have been performed using virtual worlds in clinical settings, including training programs for nurses, hospital staff and physicians in clinical medicine, public healthcare and radiotherapy.

When reviewing research about professional societies and communities of practice in the healthcare sector, Nestel et al. (2017) suggest that a simulated environment should support learning, practice and management of different, often unusual situations, which require timely performance and cooperation (Nestel et al., 2017). They argue the importance of collaborative support, as technical and cognitive medical skills are only one part of medical performance; equally important are non-technical, collaborative skills.

Virtualization technologies have also been used in training programs for students and staff in academic institutions and other educational communities within the healthcare sector (ibid). These virtual applications have the potential to give learning opportunities (Correia et al., 2016), where role-playing and content interaction enhance students medical skills (Hansen, 2008). One example of such a system is the CliniSpace Virtual Sim Center.

Developed by Innovation in Learning Inc., CliniSpace is a platform designed for simulated healthcare training using immersive computer-based environments (see figure 1.1). The application Virtual Sim Center was implemented as an experiment in Charles Drew University School of Medicine, an affiliate of University of California Los Angeles (UCLA). Yielding positive results, under-graduates trained on inter-professional collaboration while interacting with virtual patients (Nestel et al., 2017).

Figure 1.1: Clinispace Virtual Sim Center. From Clinispace web page (Innovation in Learning, Inc, nd).

When researching VSs in nursing education, Stokowski (2013) states that healthcare simulations act as arenas for interdisciplinary education for improving communicative skills and teamwork, and can compliment traditional classroom learning (Stokowski, 2013). She further suggests that VSs and *serious games* can prepare students for clinical work, bridging the gap between theory and practice (Stokowski, 2013). A serious game is defined as an interactive, computer-based software application developed for other purposes than for entertainment (Ritterfeld et al., 2009). According to Ricciardi and Paolis (2014), serious games are developed to be less realistic than VSs, also adding some form of entertainment value closer to that of a video game (Ricciardi and Paolis, 2014). As illustrated in figure 1.2, they created a computer game spectrum based on the work of Qin et al. (2010).

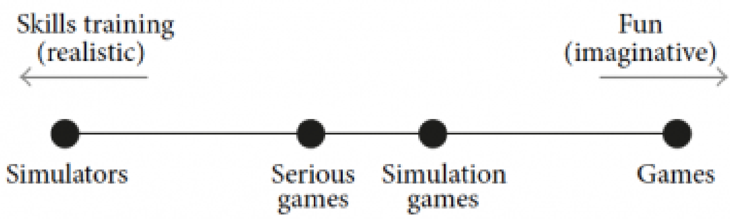

Figure 1.2: The computer game spectrum.

Creutzfeldt et al. (2010) examined the implementation of scenario-based CPR training in the healthcare curriculum at Karolinska Institute in Sweden, and whether the system had a positive effect on the students' experience and knowledge retention (Creutzfeldt et al., 2010). The collaborative simulation contained four different scenarios. Measuring knowledge, concentration and self-efficiency, they found evidence of increased concentration and self-efficiency, concluding that simulation-based virtual worlds are appropriate methods for the training of medical students. They explain that more research is needed to understand the impact this technology has on students in emergency medical training. Participants reported that the experience was enjoyable and suitable for medical training, but asked for more variation and richer environments.

Researching clinical practice and VSs, I have found little evidence on the subject of randomized scenarios, where the user is presented with different possible actions and *contingencies*, or whether unfolding scenarios and the flow of events are adequate for supporting situated practice and teamwork. Contingencies are understood as unpredictable but possible course of future events or circumstances (Oxenford Dictionaries, 2017).

Only a few articles I have found are concerned with training for situated action through randomized scenarios containing contingencies, all developed as serious games and not realistic VSs. For one such use of serious games, Graafland et al. (2017) performed a series of studies concerning a serious game functioning as a training application for surgical residents (Graafland and Schijven, 2013; Graafland et al., 2014, 2015, 2017).

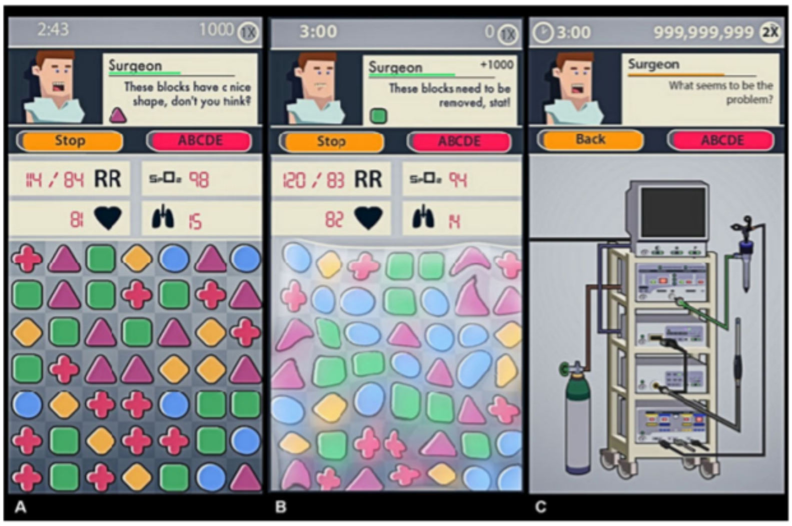

Figure 1.3: The serious game for surgical residents. From: Graafland et al. (2014).

Even though the application was designed as a block-based mini-game (see figure 1.3), and not a high-fidelity reconstruction of reality, the results of the study indicate that the game had a positive effect on the participants *situated awareness*, i.g. their ability to perceive and comprehend their surroundings so that to act according to possible future events. With 37 problem scenarios the game trained surgeons to recognise and respond to equipment failure. They found that participants who had used the serious game responded better to equipment-related problems during medical procedures than colleagues trained only with the standard curriculum.

1.1.2 Designing virtual training applications for collaborative work and practice

Although there have been reported many benefits from using a VS in both academic and professional healthcare, there have been cases where participants have found the use of the technology challenging (Howard et al., 2011). This is something that developers of virtual training systems need to consider throughout the design process; creating comprehensible interfaces and intelligible interactions can ease the process of implementing new technology in healthcare curriculums.

Benford et al. (2001) have shed light on design requirements of VSs, identifying scalability as one fundamental challenge (Benford et al., 2001). When they first introduced the problem back in 2001, they mostly referred to the graphical and behavioural complexity of the virtual applications. Since then, increased machine power has given us hardware able to support more complex graphical representations. Also, game development platforms can also support branching game scenarios, giving the opportunity to create more enhanced and evolving scenarios at a lower cost than before. This was partly explored by Graafland et al. (2017), which used the low-scale mini-game with randomized, controlled scenarios for training decision-making and problem-solving skills (Graafland et al., 2017). This underline the importance of studying situated and contingent action within scenario-based training programs for health professions. Further, it is also useful to see how this will effect teamwork.

I have found little research using concepts from CSCW, like situated awareness and articulation work, when understanding VSs as training applications for collaborative work practice. In the light of collaborative work, the concept of formal articulation work has been used trying to understand how shared references help teams orient, navigate and collaborate in shared information spaces (Muller et al., 2005). Although concluding that these references are important, Muller et al. (2005) states that more research is needed to understand the effect they have on work practice. Studies with the purpose of uncovering design requirements for collaboration within shared information spaces show that VSs have potential as safe training tools for medical procedures. I'm not however aware of research findings supporting VSs as tools for articulation work in clinical practice.

This section has shed light on the use of VSs and serious games for learning in the healthcare sector. In the next sub-chapter, I review concepts from CSCW that frame an understanding of VS supporting clinical work.

1.2 Theory framing the inquiry

As a well established research field, CSCW covers a variety of specific problem areas and are under continual formation (Schmidt and Bannon, 2013). CSCW slowly emerged from the design and development of computer-based systems and applications of multiple computing technologies, making the very nature of CSCW an interdisciplinary research field. Systems supporting collaborative work have been a research subject since developers started using computing technology for designing what is come to be known as *interactive computing*, or on-line, real-time transaction processing (Schmidt and Bannon, 1992). Schmidt and Bannon (2013) give the example of the development of airline reservation in the 1950s, which facilitated collaborative work as shared digital representations which workers could access, interact with and modify. In the 1960s, terms like 'time-sharing operating systems' (e.g. today's e-mail systems) and 'computer-mediated communication' (e.g. functional computer networks), emerged. In the late 1980s, the World Wide Web became a global infrastructure for collaborative technologies, increasing the development of cross-platform facilities for communication. These early computer systems laid the foundation for various technological platforms and products going under the category of 'collaborative technologies' in organizations. The process of developing and improving technological platforms for collaborative purposes are still 'ongoing and open-ended', as researchers, developers and designers are realising the collaborative potential of emerging technologies and how they are related to concepts within CSCW (ibid).

Computer-based collaboration is not a discipline with strict and finite boundaries. It is often overlapping relating domains, e.g. CSCL, and other research fields like Human Computer Interaction (HCI) or Science and Technology Studies (STS). Therefore, a definition of CSCW has been hard to establish. Bannon and Schmidt (1989) explain that even though the field often crosses over to other research areas, CSCW was from its early days generally understood as an endeavour to understand the nature and characteristics of cooperative work, and focused on designing adequate computer-based technologies supporting this work (Bannon and Schmidt, 1989). The main focus of CSCW is the user-oriented perspective of collaborative work, where complex interactions among people are supported by socio-technical systems (Schmidt and Bannon, 1992). According to Schmidt and Bannon (1992), CSCW is a *design-oriented research area*, devoted to exploring and supporting the requirements of cooperative work.

They further conceptualise CSCW by breaking it down into the terms *computer supported* and *collaborative work*. They define *computer supported* as simply as 'to *support via computers*', further explaining the concept as a commitment to the actual requirements of the workers engaging in the collaborative work. It is an endeavour to *understand* so as to better *support*, uncovering and analysing the characteristics, i.e. the general support requirements (the what, why, when and how), of the collaborative work opposed to individual work.

Moving to *collaborative work*, they explain that the nature of collaborative work is too heterogeneous to have *one* definition, but argue that it can be thought of as *interdependent work*. By this, they don't mean 'interdependent' as having to share the same resources to get a job done, often resulting in frustrating work situations. Rather, interdependent work describe work situations where 'A' relies positively on the quality and timeliness of 'B's work and vice versa [..]" (ibid, p. 8). By this understanding, the work is *mutually dependent* and therefore require collaboration and articulation work to get done.

1.2.1 Designing for collaboration

According to Schmidt and Bannon (1992), collaborative work constitutes characteristics like 'dynamic patterns of interaction' and 'various problem-solving strategies', which are essential in demanding work environments. These characteristics present challenging problems for the development of computer-based systems designed with the purpose of supporting collaborative work.

Benford et al. (2001) highlight the importance of the physical space as a resource when negotiating social interactions, awareness and shared artifacts (Benford et al., 2001). Further, they describe social conventions as fundamental for communication. This is supported by Muller et al. (2005), where they in their paper 'Shared Landmarks in Complex Coordination Environments' investigate what they call *social landmarks*. These landmarks are shared perceptions and conventions established through social practice and negotiation, and are essential for effective collaboration. Benford et al. (2001) and Muller et al. (2005) argue that knowledge-transmission between individuals require these landmarks; without shared perceptions, communication would be meaningless. Therefore, developers of VSs should build simulations based on the locally situated conventions, like vernaculars, of the target group. Heath et al. (2002) explain how surgeons, anaesthetists and nurses working in close collaboration at hospitals 'configure awareness', which help them coordinate their joint activity.

Blomberg and Karasti (2013) propose a similar theory, where they in the paper 'Reflections on 25 years of ethnography in CSCW' shed light on awareness theory, claiming that users of shared, synchronous or asynchronous collaborative methods require cues or notifications about occurring actions. Therefore, VSs need to support *situated awareness*, as workers' collaborative abilities are depended on both subtle and overt cues, e.g. overhearing, speech, or other gestures, allowing them to become aware of each others action.

This sub-chapter has shed light on the research field CSCW and its endeavour to create digital support systems for easing workplace collaboration. Further, developing adequate systems for hospital work have been challenging, as this work is complex and locally situated. Creating collaborative systems for clinical work are necessary, as it will ease the flow of information and make it accessible to practitioners, which will have a positive impact on the performance of medical work.

1.3 Description of the prototype developed by Attensi

The following sub-chapter gives a description of the prototype created by Attensi. The description is not given as an assessment of the prototype. Rather, it will present the reader with detailed information so as to better understand further references to the prototype and are important to understand the results from the interviews, observations and usability tests. It is also important to understand that the VS is not a tool used as a support mechanism during thrombosis treatment. Rather, it is a training method for practitioners between treatments.

The prototype is developed using ØHT's standard operation procedure describing the work of every practitioner involved with the treatment. From this, Attensi created a flowchart, explaining the ongoing activities of each practitioner at any given time during the thrombosis performance. Illustrated in 1.4, this is the core process model which has been used to transform the written protocol into a virtual simulation.

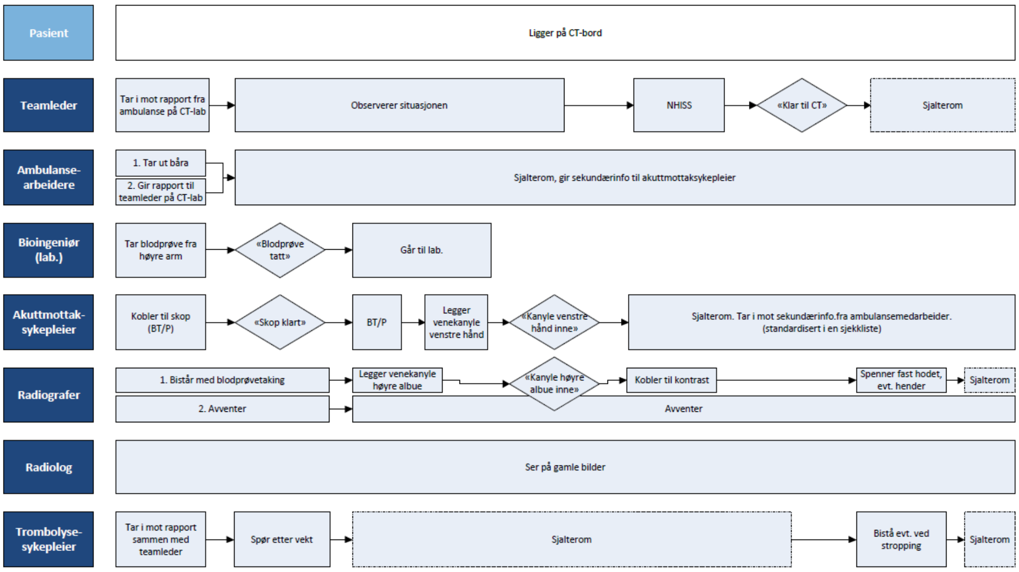

Figure 1.4: Excerption of the flowchart created by Attensi, acquired through the courtesy of the project manager.

In addition, Attensi obtained further information about procedure from conversations with the head of department, the project manager, and various senior doctors at ØHT. They have also observed the thrombosis treatment.

The screen layout, illustrated in figure 1.5, consist of the following screen elements; information bar, objectives and dialogue options. In the top left corner, the user is presented with an information bar (see figure 1.6) showing total score, treatment time and progression. The score increase or decrease based on user's actions and choices throughout the simulation. The point system are created in a way that some dialogue option or activities are more correct than others. A correct response can therefore yield e.g. 25 points or 100 points. The user is alerted about point-updates through a pop-up function in the middle of the screen.

Figure 1.5: The screen layout.

Next, the user sees the treatment time. This timer starts during the treatment, when patient arrives at the hospital, and are further explained in the next section. Note that this clock is a representation of work procedures, and do therefore not represent real time. Developers have tried estimating the time it takes for certain actions, adding it to the timer throughout the procedure.

Figure 1.6: The information bar presented in the top left corner of the screen.

The process steps are presented at the bottom of the information bar; receiving patient, before radiology, after CT without contrast and after radiology. These are colored blue as the user progresses throughout the simulation.

Bellow this information bar, the user is presented with the current objectives, e.g. picking up the phone or receiving ambulance driver (see figure 1.7).

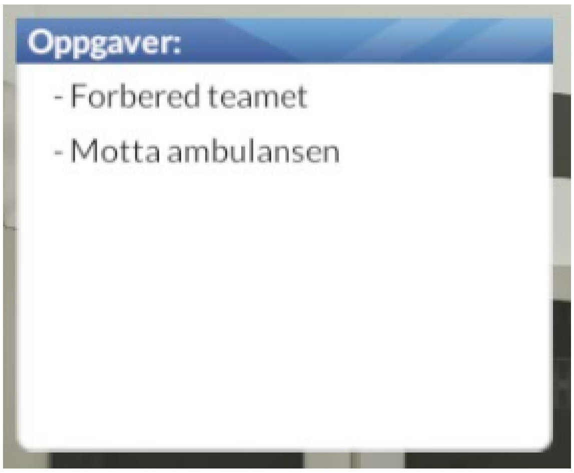

Figure 1.7: The current objectives the user is to perform, presented bellow the information bar.

Dialogue and options are presented at the right side of the screen. The top text field contains receiving information or questions from team members. The bottom text field contains dialogue options for the player.

Prototype event sequence

To get a better overview of the prototype, I have broken it down into the following logical sequences:

1. Introduction
2. CT observation room 01
3. Arranging order of activities
4. CT scan room 01
5. Creating check-list
6. CT scan room 02
7. CT observation room 02
8. Results and summary

1. Introduction. As the user launches the application, s/he is introduced to the prototype by a descriptive text introducing the purpose of the simulation and the project. After, the case is presented; the user are to act as the team leader of a thrombosis procedure, and are to receive patient and observe thrombosis procedure. Based on knowledge obtained during the simulation, the user must decide whether to initiate the injection of thrombosis medicine.
2. CT observation room 01. The user starts the simulation in the CT scan observation room. User receives a phone call from the ambulance personnel, informing about condition of incoming patient. User chooses how to answer. See figure 1.8.

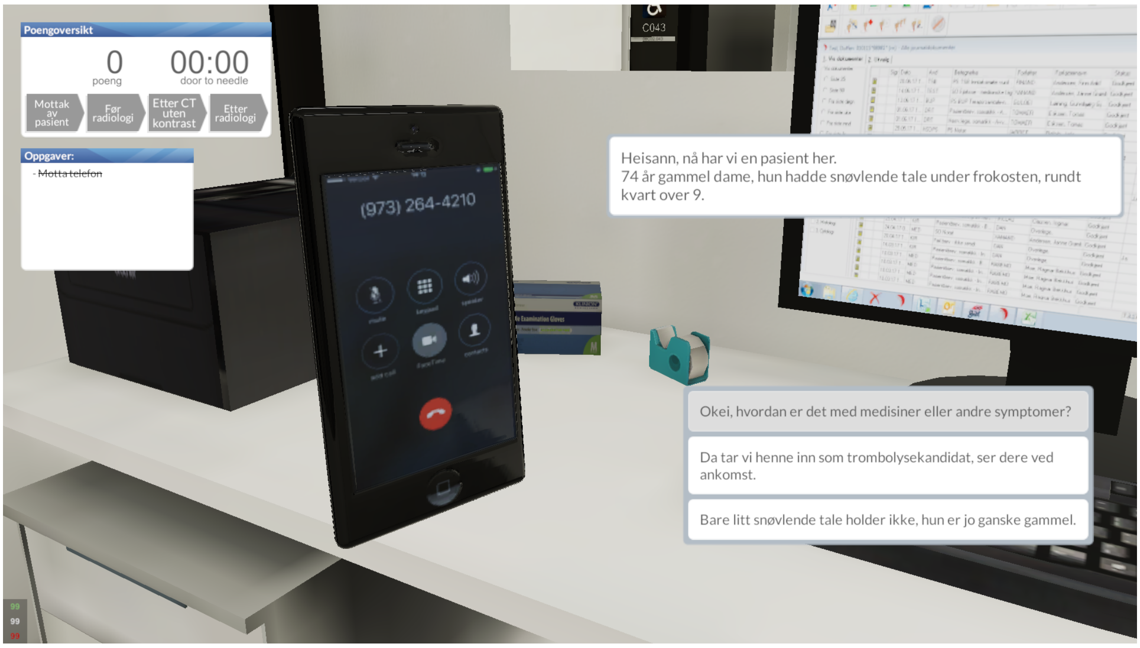

Figure 1.8: User chooses dialogue option.

3. Arranging order of activity. Next, user is presented with an in-game scheme, where s/he is to arrange the order of activities the team leader is to perform before the ambulance arrives with the patients, including checking patient journal, call team members, activate thrombosis alarm signal and meet ambulance. See figure 1.9. After, the user proceeds to checking the patient journal which present information about patient's medical records.

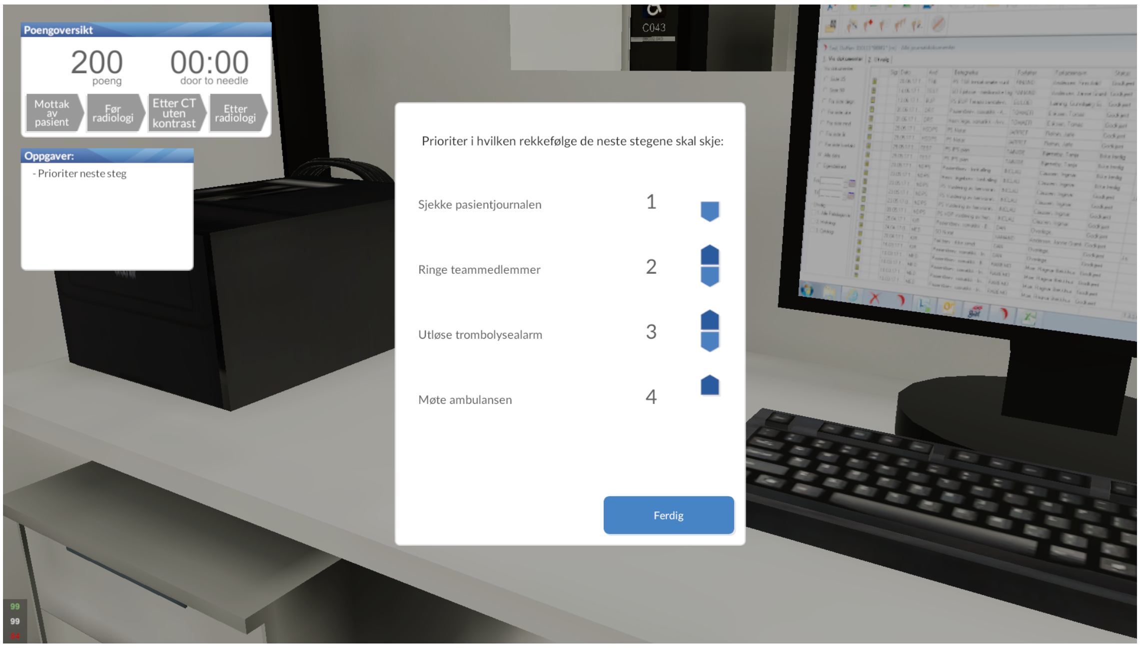

Figure 1.9: Arranging activities.

4. CT scan room 01. The user is then moved into the CT scan room, where s/he is 1) introduced to the team members, and 2) challenged in a time event. See figure 1.10. In 1), the user must evaluate if every member is present, in which the player can proceed to briefing. If not, user must click and call in the last member. This is randomized, and varies between playthroughs. In the second challenge 2), the user have 30 seconds to find the errors that needs to be corrected. These errors varies between playthroughs, but there are always two different errors, e.g. wrong placement of team member or equipment.

Figure 1.10: The time event.

5. Creating check-list. The user must create a check-list based on possible activities. These includes calibrating CT-machine, clean patient table, fasten patient head, perform clinical examination (NIHSS), take blood sample from right arm, take blood sample from left arm, fasten legs, inject cannula in right elbow, and inject cannula in left elbow. Of these possible actions, which varies between playthroughs, only five is correct. See figure 1.11.

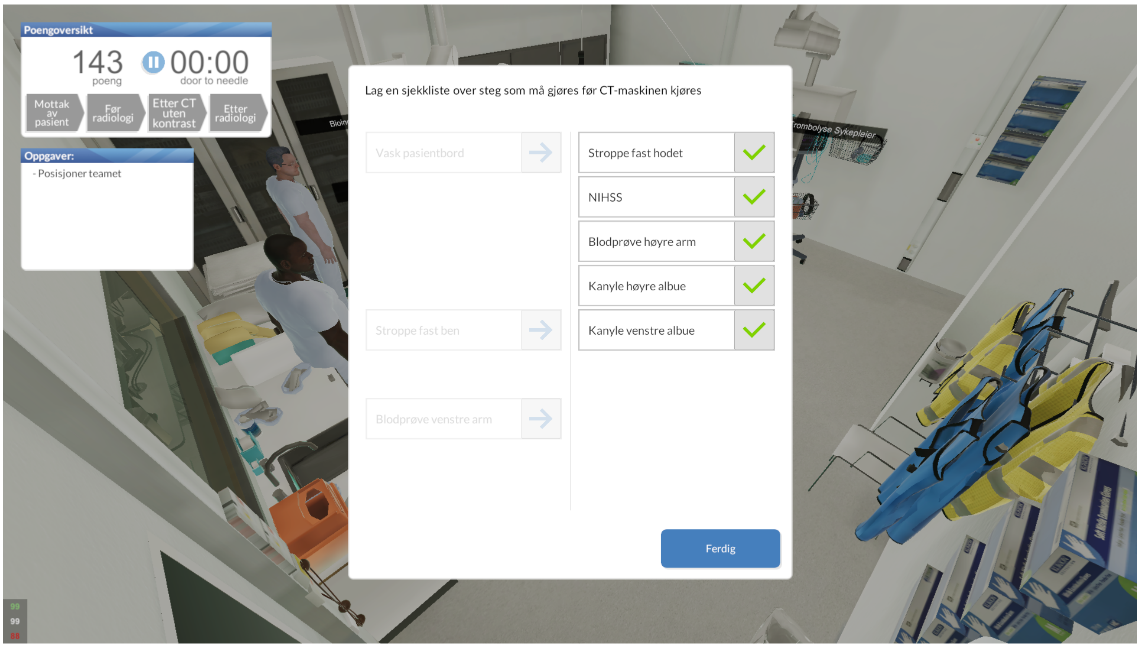

Figure 1.11: The creation of the check-list.

6. CT scan room 02. In this section of the prototype, the ambulance workers arrives with the patient. In the top left corner the timer showing treatment time starts. The user are positioned with a clear overview of the CT scan room and have to perform a series of steps before being allowed to proceed with further thrombosis treatment. This is the most interactive parts of the simulation, where the user has to:

- Follow the check-list s/he made during step number five.
- Receive patient journal and get a briefing from ambulance personnel by clicking on the ambulance worker character.
- Clicking on virtual workers to inspect and correct work activities (see figure 1.12).
- Click on different part of patient lying on the CT scan table. Pressing on elbow or the back of the hand for venipuncture. Press on head to strap head and feet to take of shoes (see figure 1.13). The user must choose which team member to perform the activity in both event.
- Perform clinical examination (see figure 1.14).
- The button for proceeding to actual CT-scan can be clicked after user have performed these steps.

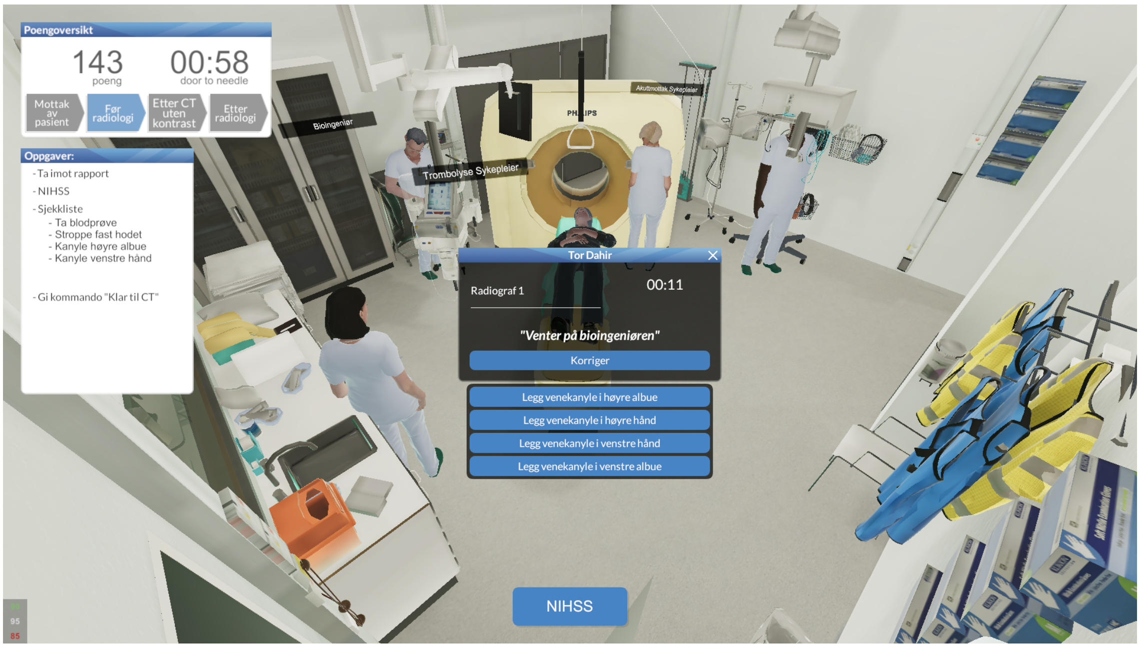

Figure 1.12: Inspecting and correcting co-worker's activity.

Figure 1.13: Choosing which worker that are to take off patient's shoes.

Figure 1.14: Performing the clinical examination

7. CT observation room 02. Finishing in the CT observation room, awaiting CT-results.

8. Results and summary. This is where the prototype ends, explaining to the user that by proceeding, s/he can inspect a time graph of the activities performed by the different virtual characters, colored green og red based on users choice (see figure 1.15). Where the former represent right procedure and the latter shows wrong answer. By scrolling right, the user gets an overview of the rest of the procedure which are to be created if the project are presented with further funding.

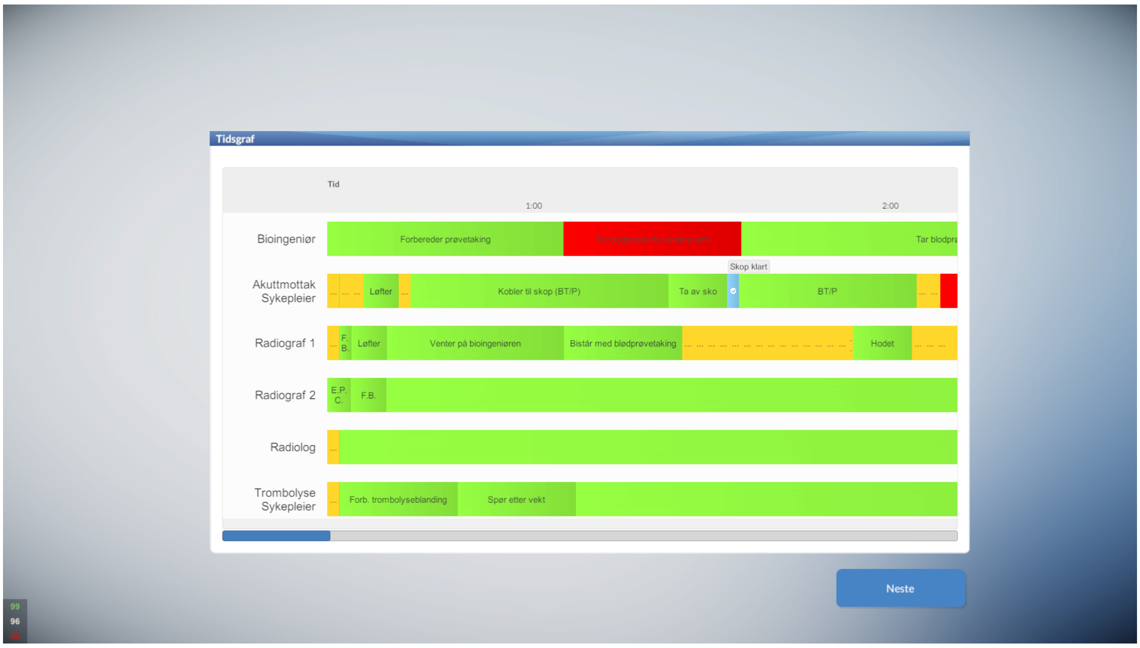

Figure 1.15: Inspecting the time graph.

The user is also presented with a summary, showing total points, treatment time and time difference from optimal time (see figure 1.16). Here, the user also get indications for improvements.

Figure 1.16: Results and summary.

1.4 Report outline

This chapter introduced the thesis' research questions and the methods that have been used for answering these questions. Further, the chapter covered relevant literature regarding the use of virtual simulations and serious games designed for medical students and workers, also introducing the research field CSCW and the prototype developed by Attensi.

Chapter 2 sheds light on theories within the research fields of CSCW and practice theory, with concepts like awareness, articulation work and communities of practice, all adding to a theoretical framework relevant for understanding the problems in and importance of my inquiry.

Chapter 3 reports the research methods I've used during the course of this study, describing the process of how I've proceeded for answering my research questions.

Chapter 4 summarize the results from the research methods in respect to my research questions.

Chapter 5 discusses what the findings from this study means for the research fields and concepts addressed in chapter three, and how this study has shed light on implications for design for the development of VSs that is to support collaborative work settings.

Chapter 6 concludes and summarizes the contribution of this study. Presents possible directions for future research.

Chapter 2

Theoretical framework

In this chapter, I explore theories and concepts relevant for answering my research questions. First, I address theories of awareness, shedding light on how people engaging in collaborative work need to stay aware of other co-workers, the current status of work activities and the environment. Awareness is a fundamental part of all collaborative work, and are concerned with how people use social, temporal, spatial and activity awareness cues for perceiving information about co-workers and ongoing events.

Next, I inquire into articulation work. This secondary work process is essential for the management of all work featuring mutual dependency - where individual workers positively rely on the timely performance of other workers. The complexity of collaborative work are often managed using coordination mechanisms, e.g. the standard operating procedure at the hospital, helping to reduce the overall complexity of the work. These mechanisms are however often inadequate, as they do not support the situated nature of collaborative work settings and the work that needs doing when dealing with contingencies.

I also look into practice theory to shed light on how employees involved with the thrombosis procedure are a part of a community of practice. By participating in this community, practitioners gain knowledge about the specific features of their respective work activities. Lastly, I inquired about canonical and non-canonical work, shedding light on the differences between formal work descriptions developed by the workplace management (like the standard operating procedure function as the coordination mechanism of the thrombosis treatment), and the informal work practices that is performed due to the situated nature of work, making the canonical work descriptions always underspecified.

The goal of this chapter is to construct a framework to gain further understanding of how VSs can be used to support the collaborative work and the practice the employees at the hospital perform during the treatment of emergency procedures. This framework is presented as a flowchart at page 32, illustrating how the concepts used in this chapter relate to one another in the process of complex collaboration.

2.1 Theories of awareness

Awareness research has been a part of the CSCW research field over the past decades, as an attempt to understand the basic requirements for the development of computer systems supporting social interaction in groups and communities (Gross, 2013). These studies have shed light on the importance of awareness and its impact on collaboration (see e.g. Gross et al. (2005), Rittenbruch and McEwan (2009), Schmidt (2011), and Dourish and Bellotti

(1992)).

The meaning of the word 'awareness' highly depends on its context (ranging from consciousness to recollection). Therefore, a distinct definition of the term has been debated (Gross, 2013). According to Gross (2013), the term 'awareness' has been used and combined by many researchers, leading to *general* awareness (Gaver et al., 1992), *shared* awareness (Borning and Travers, 1991), *mutual* awareness (Rittenbruch and McEwan, 2009), and *workspace* awareness (Gutwin and Greenberg, 2002). Even though the term is not explicitly defined, Gross (2013) states that

> "[..] awareness is a user's *internal* knowing and understanding of a situation including other users and the environment that is gained through subtle practices of capturing and interpreting information [..]" (ibid, p. 8).

Further, Schmidt (2011) found two corresponding concepts when investigating previous awareness studies involving awareness support systems; technology-oriented awarenesses and ethnographically-informed awareness (Schmidt, 2011). In the former, the system provides information about other users within the system. In the latter, awareness is the outcome of the user's activity.

He explains that awareness support are an essential part of technologies which purpose is to support collaboration, and have among other things given rise to the term *groupware*. Here, the user are made aware that s/he in some form is a part of a group, offering activities and social interaction, and therefore distinguishes itself from other types of collaborative technologies, with examples ranging from social media platforms like the Facebook chat system, to shared editors like Google Documents and Overleaf (Gross, 2013). He argues that cooperative setting have three important dimensions; space, time and connection among users. These dimensions are fundamental when creating a system supporting either synchronous or asynchronous collaboration. In some form or another, the users should receive information about real-time co-presence (i.e. on-line status) and co-workers' activities. The term awareness is here used to describe systems which allow work-oriented information about fellow co-workers, general information about who is present in the system, detailed information about each user within this system and any changes done within these shared workspaces.

He explains that *technology-mediated awareness* is an important part of systems supporting collaboration, e.g. presenting task-specific, mutual, cooperative and/or coexisting awareness information about users. Awareness can however not be *produced* by technology, nor be a *property* of a technological workspace. Rather, awareness is a 'learned, embodied and skillful action' (ibid, p. 8). He further quotes Robertson (2002), stating that

> "Awareness can only be achieved by the skillful activity of participants in a shared space if the resources they have learned to recognize, and therefore understand, are publicly available to them." (Gross, 2013, p. 41).

Previous ethnological studies have found that "[..] cooperative work is based on implicit coordination among the people involved" (ibid, p. 5), and sheds light on team work and practice in a larger context. This practice is further addressed in section 2.3.

In this understanding, awareness is concerned with each individual's comprehension of his or hers situated activities and environmental surroundings. It is more of an internal process in the individual's mind, and are not explicitly bound by and visible in the working environment. He further explains that rather than being a 'point in time', awareness is a *dynamic construct*, which

> "[..] goes beyond static and constant information and involves on the one hand careful attention to ongoing events and actions and on the other hand subtle production and communication of information to each other." (ibid, p. 5)

In collaborative work settings, groups are managing 'the process of collaborative working' using awareness information (Dourish and Bly, 1992). Awareness about co-workers provides context for ones own work, leading to an understanding of how each individual work activity is relevant for, and how it contributes to, the common goal of the group.

When developing systems for collaborative work, it is important for the user to be able to display and monitor awareness information. Schmidt (2011) explain how developers must consider the *effort* that is required of the user when achieving and maintaining awareness; if the workers are located in the same physical space, they normally have an understanding of the work being performed and can with little effort registrate and monitor what the fellow workers are doing. However, if the workers are in different locations, awareness information needs to be mediated through the technological system. Further, Gross (2013) explains how the mediated information needs to be created for 'proper interpretation' so that it don't cost the user significant effort to interpret and make meaning of the information (Gross, 2013). He explains that systems should help users keep a low 'coordination effort' by supporting *effortless coordination*; while the workers are coordinating the collaborative work, it should be made easy to obtain and maintain a mutual understanding of the work that is being performed by different co-workers. The process of awareness information exchange should happen in the background of the ongoing work. He further explains that there is a tension between supporting user-oriented awareness and supporting automation within technological applications, and that this makes the development of systems supporting seamless awareness difficult.

2.1.1 Context-based workplace awareness

Bardram and Hansen (2010) explain how people engaging in co-located, collaborative work use subtle mechanisms, which helps align different work activities seamlessly, tacitly, and in a highly sophisticated manner so as not to interrupt each other (Bardram and Hansen, 2010). They use the term *context-based workplace awareness* as a term describing "mechanism of establishing awareness about the activities in a workplace based on access to information on work context" (ibid, p. 3). This type of awareness is focused on situations where the worker engage in complex collaborative work that involves frequent interruptions and changes in activities, often in a work environment dealing with life- and time-critical situations. They argue that this type of awareness is dependent on "collecting, processing, distributing, displaying, and sharing information" in a highly situated and constantly changing work environment (ibid, p. 3).

To manage these activities, workers present and perceive *context cues*. These cues mediate workplace awareness as a way of gaining information about surrounding events and activities in the workplace, but also informing co-workers about ones own ongoing activity. Schmidt (2002) argues that collaborative work never occurs in an abstract space, but in a work environment full of different context cues. Using these cues, competent practitioners align and integrate their activities (Schmidt, 2002). Bardram and Hansen

(2010) explain how context cues communicates "current status of people, places, and activities" (ibid, p. 5). They found that working hospital staff constantly present and receive these cues, especially when faced with deviations, enabling co-worker to efficiently accommodate for contingencies. As an example, they explain how medical operations may be delayed due to unforeseen complications, and therefore require workers to adjust activities accordingly.

Further, Bardram and Hansen (2010) explain that designing systems supporting busy clinicians' awareness of relevant events within the hospital, enabling them to more efficiently align and coordinate work activities, are challenging. However, designing systems supporting context-based workplace awareness by monitoring and displaying context cues are important, as it will help practitioners make sense of ongoing events and situated activities in the collaborative working environment at a hospital.

2.1.2 Awareness types

Several studies have found four important factors when coordinating collaborative work within the hospital, similar to Gross's (2013) notion of space, time and connection among users. Studies performed by Bardram and Hansen (2010) and Muñoz et al. (2003) found that mediating awareness between co-worker can be divided into four closely related dimensions: social, temporal, spatial and activity awareness (Bardram and Hansen, 2010; Muñoz et al., 2003). In all four of these dimensions, context cues help display and monitor the 'what, when, where and who' in a shared work environment.

Work is a fundamentally social phenomena and workers are required to possess diverse social skills (Schmidt, 2002; Gross, 2013). Bardram and Hansen (2010) explain how mediation of social cues help co-workers align their work activities according to each other. As an example, they explain how experienced nurses interpret social cues given by surgeons to provide the right surgical instrument at the right time (Bardram and Hansen, 2010).

They observed how clinical staff contentiously monitored co-workers activities, and at the same time made sure that their own activities were visible cues for others. This type of *mutual* awareness of activities and whereabouts of team members are important for collaboration, where social cues contribute to knowing exactly when and whom to contact.

Further, they explain that social awareness cues help minimize interruptions as workers are presented with information about when it is appropriate to engage in direct communication. Social awareness helps minimize obtrusive activities, reducing the consequences of badly timed interruptions in the hospital. These disturbances can have very serious consequences and have a negative impact on the quality of the work, as surgeons may lose concentration and operation time may increase.

Social awareness cues are especially important if the work is distributed over time and space (i.e. not co-located), and needs to be mediated through e.g. instant messaging or on shared schedules on whiteboards in the hospital. Here, workers are presented with information about the location of co-workers and the status of operations, mediating social awareness information between co-workers.

However, designing for social awareness has proven challenging. When reviewing the history of computer supported awareness, Gross (2013) found various design tensions, stating that it is hard and sometimes even impossible to find one solution that meets all the requirements for supporting awareness that mimics mutual awareness across time and space (Gross, 2013). One of these tensions are *availability.* He further refers to the work of Berlage and Sohlenkamp (1999), stating that

> "awareness... allows users to coordinate and structure their work, because they can see what others are working on. Additionally, it enables users to check the availability and accessibility of others, providing a base mechanism for establishing communication" (Gross, 2013, p. 29).

Further, temporal awareness in clinical settings describes hospital employees' awareness of schedules, temporal rhythms, temporal patterns and temporal cycles (Bardram and Hansen, 2010). This type of awareness are concerned with how practitioners in the hospital align work according to planners and schedules. It also include how practitioners adjust ongoing activities and schedules according to unforeseen events and contingencies.

Spatial awareness describes how workers are aware of what is happening in a specific room or in different locations within the workplace. As an example, Bardram and Hansen (2010) explain how every practitioner involved in a medical procedure must know the current status of the operating room, so that their individual tasks corresponds with co-workers'. Here, workers use important context cues, like observing current activity, communicating or notifying co-workers about the status of a particular process.

Lastly, clinical practitioners are balancing many different activities during their work-day, and are required to maintain awareness of both main and associated activities simultaneously. There are many ways to maintain activity awareness, e.g. constant monitoring of co-workers' activities and obtaining the status of these activities. Based on this monitoring, workers adjust their own activity so that it align with co-workers'. Bardram and Hansen (2010) further write that an important feature of medical work is being able to prioritize incoming tasks. Activity awareness helps practitioners at the hospital maintain an overview of the current state and progression of these tasks, so as to make informed decisions about the importance of each case.

2.2 Articulation work

As briefly addressed in chapter 1, articulation work is a secondary work process concerned with managing, coordinating and dividing collaborative work processes (Schmidt and Bannon, 1992). Articulation work is concerned with the "[..] what, where, when, how, by means of which, and under which requirement[..]" during a coordinative performance, and is essential for all work that is mutually depended (ibid, p. 9). It is concerned with how teams use *shared references* to orient and navigate work processes, both in real life and in digital, shared information spaces (Muller et al., 2005). These shared references can be material artifact or take a more abstract form, like informal workplace norms and practices.

Similar to these shared references, Schmidt (1994) explains how collaborative work requires different forms of direct articulation using what he called different *modes of interaction*, which are dynamical combined and meshed depending on the work, situation and options for communication (Schmidt, 1994). These modes can be seen as closely related to concepts addressed in the sub-chapter regarding theories of awareness, and includes 1) formation of reciprocal awareness, 2) directing attention, and 3) negotiations.

1) A reciprocal (or mutual) awareness between co-workers are (normally) a prerequisition for seamless articulation of collaborative activities, and involves monitoring co-present

colleagues. 2) Further, he explain that by directing the attention of other team members towards problems, disturbances and dangers in the field of work, they can coordinate and accommodate for deviations, and proceed with the work process. 3) Lastly, he explain how collaborative workers must engage in consultations and negotiations, especially in situations characterized by uncertainties. These situations involve various negotiation and decision making process. These modes of interaction are all managed using different *means of interaction*, e.g. monitoring, highlighting, pointing and talking.

The appropriate mode and mean for interaction all depends on the characteristics of the situated collaborative work arrangement; the degree of interdependency between workers, visible and notable risks, or if the work has a time critical nature and requires more rapid articulation of tasks.

2.2.1 Coordination mechanisms supporting articulation work

Collaborative work settings call for adequate management tools to reduce the overall complexity of the work. These tools are referred to as *mechanisms of interaction* (Schmidt and Bannon, 2013; Schmidt, 1994), *pre-hoc representations of work* (Bardram, 1997), or *coordination mechanisms* (Cabitza and Simone, 2013). These mechanisms are all concerned with the overcoming of various dependencies in the organizational work.

In the article Computational Coordination Mechanisms: A tale of a struggle for flexibility, Cabitza and Simone (2013) give an overview of the history of different technological systems developed to support collaboration in workplaces. They found that scholars already in the late 60s aimed to abstract activity patterns, looking to create systems supporting the needs of different organizations (Cabitza and Simone, 2013). Schmidt and Simonee (1996) describe the concept of coordination mechanisms as a generalization of the many types of artifacts used for the coordination of work in different domains (Schmidt and Simonee, 1996). These mechanism includes standard operating procedures, classification schemes, time tables, production control systems and schedules in hospital work.

The nature of coordination mechanisms are multifarious, as the concept is a generalization of different artifacts. However, they argue that a coordination mechanism

> "[..] is a specific organizational construct, consisting of a coordinative protocol imprinted upon a distinct artifact, which, in the context of a certain cooperative work arrangement, stipulates and mediates the articulation of cooperative work so as to reduce the complexity of articulation work of that arrangement." (ibid, p. 180)

They further explain that coordination mechanisms are made up by two different devices. First, a coordination mechanism is a protocol containing a set of procedures and conventions, mediating the formal work descriptions of each profession. Secondly, a coordination mechanism can be an artifact acting as a proxy, imprinted with key components of the organizational procedure, mediating these to the workers. Further supporting this, Cabitza and Simone (2013) argue how coordination mechanisms are *artifactually imprinted protocols*; devices and structures distinctively used and perceived as tools for supporting collaboration (Cabitza and Simone, 2013).

As an example of a formal procedure articulating work, a *plan* is one such coordinative resource. Defined by Suchman (1987) as 'representations of projected action', plans describes the work that needs doing, and are an effective way to present work (Suchman, 1987). Often referred to as workflow systems or process models, they are sequential representations of tasks and predetermined events. Even though they are formal necessities for coordinating activities, plans have been criticised for being too rigid for everyday work; workflow systems exist in the tension between supporting smooth flow of work, and the organisations need in accounting for this work. Even though plans are used for almost all kinds of organized work and comes in various forms, it is important to separate work and *representation* of work. Because of this, Bardram (1997) argues that plans should be seen as resources, not as rigid templates of actual work (Bardram, 1997).

In it self, a plan cannot adequately represent all the work that needs doing in a workplace, as the nature of most work calls for situated interpretation and improvisation (Suchman, 1987; Brown and Duguid, 1991). Suchman (1987) explain the importance of understanding that a plan is a highly situated construction of practice. She also recognised that plans must reflect the highly situated performance of workers. Schmidt and Simonee (1996) illustrate the complexity of designing articulation systems and mechanisms using a flight-deck check-list. Although there are a lot of benefits from using these mechanism (where work is presented as a readable, step-by-step selection of safety-critical tasks), they don't stipulate "the *articulation* of cooperative activities", only the different activities in themselves (ibid, p. 29).

2.2.2 Situated action and invisible work

When designing systems supporting collaborative work, Star and Strauss (1999) explain that they must assemble, monitor and coordinate all the tasks and steps required for completing a work activity, reducing the cost of articulation work (Star and Strauss, 1999). Further, they argue that articulation work is used to get derailed activities back on track, and therefore should support work regardless of inconsistencies, glitches or breakdowns within local sub-activities of the given work arrangement by making it possible to modify ongoing tasks.

Plans are useful for representing work, but when it comes to performing this plan in practice, plans will likely see alterations or unravel because of unforeseen events. This was revealed early in the research of CSCW and workplace studies, where scholars realised the complex nature of collaborative work practice and designing sufficient collaborative technologies; supporting work in practice was as important as supporting the work in theory (Schmidt and Bannon, 2013). According to Barley and Kunda (2001), early studies revealed how all collaborative settings are characterized by continuous microcontingencies and require collaborative skills like situated decision making and adjustments (Barley and Kunda, 2001).

Multiple studies regarding plans and practice have revealed that one of the most fundamental characteristic of work is that it is impossible to foresee every possible event. These unanticipated events will obscure the sequence of the planned activity. No formal work description can plan for every contingency, and these variations, deviations and inconsistencies need to be resolved *in situ* by the employees (Blomberg and Karasti, 2013). Real life is highly contextual, and calls for *situated action.* When plans break down, workers are in the need of a *contingency* plan, a back-up plan for when the work as described in the primary plan no longer support the course of action. Because of these contingencies, Schmidt and Bannon (2013) argue that computer systems cannot be purely sequential, but has to support ongoing work independent from the current conditions of that work. It has to be able to support the transformation of a formal procedure into *contingent action.* It calls for the development of support systems with a more flexible workflow that functions as a resource rather than a rigid blueprint of the work procedures.

Further, developers of computer-based collaborative systems must also take into account the concept of *invisible work*. This kind of work is related to 'implicit articulation work'. Referring to Star and Strauss (1999) and Strauss (1988), Blomberg and Karasti (2013) explain that

> "[..] implicit articulation work (as contrasted with explicit articulation work) [..] often resides outside or beyond formal descriptions of work and frequently is unacknowledged and/or unrewarded" (ibid, p. 7).

Being a kind of back-stage activity beneath regular work routines, this work is often hidden from and goes beyond formal work descriptions. According to Blomberg and Karasti (2013), ethnographic studies strive to uncover this kind of work, as it is not a part of formal descriptions. They give an example of how document coders at a law firm must have an explicit understanding of document structure and legal practice; expertise invisible to the lawyers and therefore taken for granted.

Not understanding this kind of work when designing a new system, and implementing it in the workplace, will lead to an under-representation of the time and effort it takes to accurately perform work activities. Therefore, acknowledging this work is important when designing new collaborative work systems or other forms of coordination mechanisms, as it will reduce the probability of the system being inadequate for supporting every member in the collaborative unit.

2.3 Practice and planning

Schmidt and Bannon (1992) question how to approach the complex problem of designing systems that will change collaborative work patterns, further arguing that the drive of CSCW should be to design systems based on the ever deepening understanding of the nature of collaborative work and practices (ibid). They argue that to be able to develop information systems for collaborative work, the very nature of "collaboration" needs to be clearly understood. System designers have all too often encountered the complexity of collaborative work processes the hard way, where new computer-based systems have resulted in disruptive effects in the work environment due to the lack of knowledge and appreciation of this complexity. Schmidt (2002) explains that management of work is not achieved through passive observation of information, rather it is a result of an active and skilled practice (Schmidt, 2002). The complexity of collaborative work can be understood by analysing workplace practice using practice theory.

Similar to the CSCW research field, practice theory is a broad discipline with a variety of opinions and perspectives. Therefore, practice are not defined, or confined, to one specific theory. According to Nicolini (2012), practice theory can yield new, valuable information and a deeper understanding of social and organizational phenomena (Nicolini, 2012). In the book 'Practice Theory, Work and Organization: An introduction', he explain that practice-based approaches have since the 1970s become "increasingly influential" within various disciplines like science, culture and learning. He argue that a practice-based approach reveals how the human world are constructed - e.g. something that is made, remade and modified by the practitioners minds, bodies and tools. From this point of view, organisations and organisational work is a result of evolving practices. They are "fundamentally processual", as "ongoing routinized and recurrent accomplishment", and with close connections with social structures (ibid, p. 3). By this, he means that any and all social constructs (family, authorities and organisations) continue to exist through iterating performance of material activities. Practice is a seamless assembly of incorporated customs, as something natural in our day to day lives, and therefore often goes unnoticed. He further argue that a practice-based approach changes the way knowledge, meaning and discourse are perceived. In this context, knowledge is understood as a mastery, or a degree of mastery, of ones ability to perform social and material tasks.

Knowledge is also understood as "shared" with others, as local conventions and methods for completing activities acquired through some form of instruction or training. According to Nicolini (2012), becoming a part of a practice means learning certain attributes of that particular practice; how to act, feel, expect and vernaculate. These attributes does not belong to the individual, but are shared through a *community of practice*. Brown and Duguid (1991) state that learning is directly "connected to the condition in which it is learned", and that knowledge is individually constructed; the individual learns to become a functional part - a practitioner - of the community (ibid, p. 48).

Further, one should also consider exactly *how* individuals within these communities learn about the shared practices. This can be explained using Schön (2017) two types of reflection; reflection-on-action and reflection-in-action (Schön, 2017). The former describes the internal process of thinking back and evaluating previous experiences. The latter refers to how workers use the knowledge gained from reflecting on previous experiences, adding this knowledge to an ongoing reflection process which occurs when the individual performs new activities.

Further, Iedema (2011) explains how workers in collaborative settings use *reflexivity*, which to some degree resembles Schön's (2017) reflection-in-action, but it extends to how co-workers monitor each other and affects ongoing events. This reflexivity is collaborative, open-ended and have an immediate effect on the activities being performed. This reflexivity is an internal process where practitioners realise and manage problems and uncertainties in collaborative situations. Iedema (2011) explain that "[..] reflexivity is a fully internalised and socially distributed monitoring and adjusting of the safety gradient of practice" (ibid, p. i84).

When performing work, practitioners use 1) knowledge of the work as represented in that work's coordination mechanism, and 2) interpretation of current events of the work that is being performed. When used together, practitioners are able to perform both standardized work and accommodate for contingencies through improvisation and reflection on former procedures. This way, coordination mechanisms and past experience functions as articulation methods for reflection *on* action, giving a basis for reflection *in* action, resulting in a more efficient and safe performance of situated activities.

2.3.1 Canonical and non-canonical work

Brown and Duguid (1991) explain how ethnographic studies of workplace practice have shown that the way people work usually differs from formal descriptions developed by the organisational management. Reliance on these *canonical* work descriptions often blinds the organization to the *non-canonical* practice (Brown and Duguid, 1991). Where canonical work is understood as formal work description, non-canonical work are the 'work-arounds', which are essential to the services provided by all organisations. The term points to the complexity of the practices of the abstracted work-flow the management of each organization has developed and expect the workers to uphold. Formal descriptions, like plans and schedules, are starting points, giving indications of how the work is to be performed. However, as they are single predetermined routes with no alternatives, they cannot fully describe the non-canonical practice. Because of this, formal descriptions of work are always underspecified (Koschmann et al., 2006). Further, Brown and Duguid (1991) explain that formal descriptions are an *abstraction* of actual practice, and that these abstractions falls short of the actual work that needs to be performed (Brown and Duguid, 1991). Canonical work is therefore a mere reflection of practice, actually reducing the amount of information given to the employee about the work, leaving the employee to bridge the gap between formal description and informal practice. They develop an understanding of the work from the actual work conditions as they arise, and not through training programs and descriptions. As formal work descriptions breaks down due to contingencies, this understanding is used as improvisational methods when solving a current problem.

Brown and Duguid (1991) argue that "[A]bstractions *detached from practice* distort or obscure intricacies of that practice" (ibid, p. 40). Without understanding these intricacies, the practice - the work that needs doing - will never be fully understood and can neither be learnt nor evolve.

In the light of these informal work processes, Nicolini (2012) explains that initiative, creativity and individual performance are key elements essential for all practice theory, because performance of practice "requires adapting to new circumstances so that practising is neither mindless repetition nor complete invention" (ibid, p. 5). It is the communities of practice that are in contact with the actual work environment, and will try to develop methods that bridge the gap between the canonical and non-canonical work, because the inadequacy of the abstracted directive approach makes the workers jobs more difficult to accomplish. Formal documentation will always break down however well it is designed, in large part because documentation tells workers what to do, not why. But also, as we have seen, because of the situated nature of collaborative work; even though a doctor has performed a clinical procedure multiple times, there is always a novelty with each new patient; each belly is a little different (Koschmann et al., 2006). As Koschmann et al. (2006) explain, "anatomy texts provide the roadmap, but the work of mapping what is seen to given anatomic categories never ends" (ibid, p. 10). There are times in which the unfolding procedure becomes an essential resource for sense-making within the surgical team, particularly sense-making related to object instantiation.

In the healthcare sector, designing for practice is already an important subject defined as 'everyday clinical work'. This is work that unfolds in practice, and are accomplished not by the management designing the formal plans, but by the personnel in direct contact with the patients (Braithwaite et al., 2016). With patient safety as a main goal, practitioners are the ones that prepare, organise and manage the various conditions around the actual situated work. Medical work futures complex, socio-technical systems, and it relies on adjustments, trade-offs and workarounds. In the book 'Resilient Health Care, Volume 3: Reconciling Work-as-Imagined and Work-as-Done', Braithwaite et al. (2016) state that one must separate work-as-done and work-as-imagined. I see this as a parallel to canonical and non-canonical work, as they further explained that clinical practices always differs from the planned and prescribed perspective of that work.

In the article 'Plans as situated action: an activity theory approach to workflow systems', Bardram (1997) states that medical work is often presented as a pre-hoc representation of work (Bardram, 1997). This representation is considered valuable as they give order to work, handle complex work situations and coordinate activity between several professionals.

Based on information about practice theory and everyday clinical work, taking a practice-based approach is essential when designing tools for supporting clinical work. Nicolini (2012) explains that when designing workplace plans, one should design for practical work requirements (i.e. what it actually takes to get the intended work done), and not the for the organizational formal description of that work (Nicolini, 2012). Further, he explains that the introduction of new technologies in the workplace alters patterns of work. Therefore, the management must pay close attention to what the employees actually do when performing work activities. Describing the work people do may not be enough as it gives a weak impression of the work practice. Recording and cataloguing practitioners doings yield what Nicolini (2012) refers to as a *weak practice program*; a shallow understanding of the actual work. A weak practice program does not capture or take into consideration

> "the meaning of the work that goes into it, what makes it possible, why it is the way it is, and how it contributes to, or interferes with, the production of organizational life" (ibid, p. 13).

Paying attention to the activity is only the first step; one also has to make sense of it. Studying the articulation of the work yields a stronger program. Consequently, practice needs to be studied "analytically" instead of descriptively.

That being said, this does not mean that developers should, or could, distance themselves from canonical work approaches; in medical work, formal work descriptions and representations of work like plans, schedules and check-lists are valuable assets as they in an abstracted form represent the complex work situation. However, there are tensions between supporting formal canonical procedures and informal non-canonical practices, leaving us with a planning paradox (Bardram, 1997; Brown and Duguid, 1991).

Brown and Duguid (1991) explain that where the canonical, rigid approach "downskills" and abstracts work, threatening "the robust working, learning and innovating communities and practice of the workplace", they are fundamental for the "order of work" which makes this downskilling a necessity within the healthcare sector (ibid, p. 53). However, there is a tension between informal practices and formal procedures within the hospital (Bardram, 1997). He explain that a typical workflow system helps to monitor, define and coordinate the flow of work within an organisation, and is a computerised representation of work activities which are often highly hierarchical and sequential, and does not take into account unforeseen breakdowns and events. He further explain that these breakdowns or events are not *exceptions* of work, but in fact important, natural activities enhancing knowledge of future work. Using a plan as a guide, learning from past events and evolving the plan thereafter, makes it an important resource for future activities. Bardram (1997) refers to a study performed by Symon et al. (1996) concerning workflow systems and practice in a Danish hospital (Symon et al., 1996). Here, they recognise the importance of planning, and how a computer system could be designed to support both the formal plan and the informal practice, bridging the gap between pre hoc plans and situated practice using the term *situated planning*. Bardram (1997) writes how Symon et al. (1996) argue that

> "a workflow system often exists in a tension between supporting a smooth flow of work within a work practice and the organisational needs for accounting for this work, and that this tension needs to be considered in design" (Bardram, 1997, p. 2).

He further argue that a digital planning system should allow content creation and modification, so that the plan becomes a updated resource as new situations featuring contingencies can be implemented, so that the contingencies are not seen as an exception of work but as a learning opportunities.

2.4 Summary

Through this chapter, I have made inquiries as to the characteristics of collaborative work and practice theories, resulting in a theoretical framework which is used to further understand how thrombosis treatment are performed by the clinical teams at ØHT.

This framework are presented in figure 2.1, which illustrates how the concepts from the research fields CSCW and practice theory are related to each other during the process of performing collaborative work.

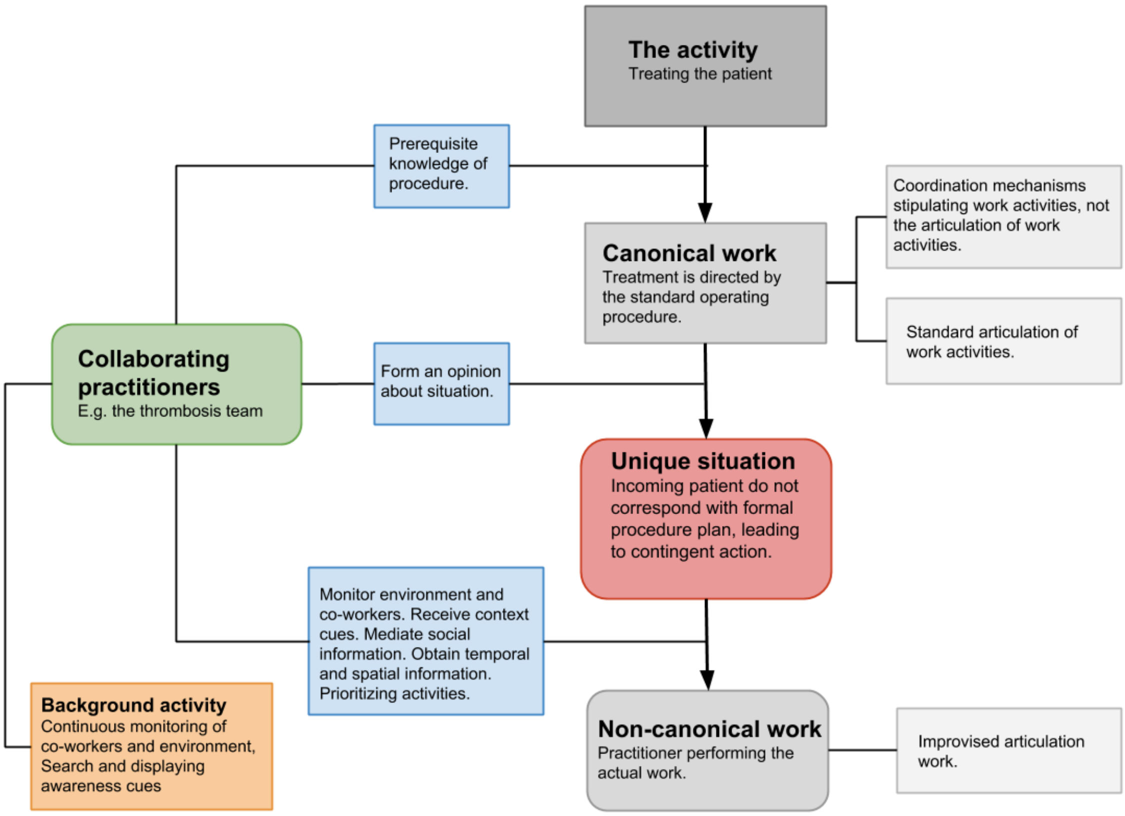

Figure 2.1: The framework model: the process of performing collaborative work.

The activity, i.e. performing the thrombosis treatment, are directed by a canonical work description which each collaborative practitioner, either through formal education, the reading of the standard operating procedure, or participation in thrombosis procedure, have knowledge of. This description is a coordination mechanism, and takes the form of a standard operating procedure; a step-by-step list of treatment activities. This procedure articulates the work performed by the thrombosis team, managing when and which worker that are to perform certain activities.

This description is developed by the management, and will most likely be insufficient for performing a entire thrombosis procedure; each new patient will likely present a unique situation, making it necessary in some extent to deviate from the canonical plan. The collaborative thrombosis team must during this stage evaluate and decide how to best proceed with the treatment.

They must use the knowledge they have of the canonical description and improvise according to the knowledge they have gained during previous treatments which also contained contingencies. This knowledge, or practice, is not constituted by formal work descriptions, rather it is derived through a community of practice. During the entire process, workers engage in background activities, continuously monitor co-workers, searching and displaying awareness cures. However, this becomes more important when the team are faced with contingencies.

Here, workers must engage in articulation work to align their activities so as to best be able to reach their collective goal. This involves different subtle or overt activities; monitoring co-workers and the environment, receiving and displaying context cues, including social, temporal and spatial awareness information. This way, they can prioritise activities and align the work more efficiently.

This framework and process model are useful when investigating how a VS can function as a task trainers for the individual workers involved with thrombosis treatment. It has contributed to an understanding of important features of the complex, collaborative and highly situated work that is performed during thrombosis procedure. Lastly, it has contributed to a deeper understanding of important features that needs to be considered when designing support systems for collaborative settings.

Chapter 3

Method

In this chapter, I present the research methods I have used when inquiring about how practitioners at the hospital perform thrombosis treatment and how the prototype of a VS are perceived by these practitioners. These methods includes field observations, interviews and user testing. Further, I explain how my thesis upholds ethical research guidelines.

As the purpose of my study is to gain a deeper understanding of the behaviour and work performed by practitioners involved with emergency treatments at the hospital, I have chosen a qualitative research approach. According to Silverman (2001), qualitative studies are designed to reveal social processes by inquiring about human behaviour in everyday situations (Silverman, 2001). When wanting to understand how people work and interact with each other and the environment in cooperative settings, and further, how this is transferred and represented when using a prototype simulating the same setting, I found that qualitative research methods are more appropriate than quantitative or mixed methods. Although there are those who questions the scientific status of qualitative research, it can according to Silverman (2001) produce both *valid* and *reliable* results.

He explains that these concepts are important for the credibility of qualitative research, which among others things are concerned with the choosing of systematic collection and analysis of data. Considerations concerning reliability includes whether the findings from the study are replicable by other researchers; whether performing a similar study will uncover the same research findings. Validity is concerned with how the findings from the study are an accurate interpretation of the collected data.

I wanted to take an ethnographic approach, as it would have given further insights into the community of practice at the emergency ward. Choosing ethnography to study this community would bring me closer to the practitioners performing the thrombosis treatment. Blomberg and Karasti (2013) explain that by participating in social life, the ethnographic researcher makes sense of the inquired social group (Blomberg and Karasti, 2013). This includes studying the group in its natural context, providing a descriptive understanding of the group as seen from the individual's perspective, all the while keeping a holistic view of the social group.

However, when using an ethnographic method, the researcher must try to be immersed into the social group and become an accepted member in the group. As an outsider without the skills or knowledge of the formal and informal norms of the workers at the department of neurology, being accepted as an insider would have proven a difficult task with the resources I possess. Also, the nature of medical work at a hospital requires a closed working systems, where outsider have limited access. As I did not have an access card, I depended on gatekeepers that could escort or vouch for my presence at the emergency ward. Having free access to observe and record the social processes of the practitioners in this particular work setting was challenging. During the course of this study I therefore chose a different approach, as the gathering of data did not uphold conventional features of an ethnographic research study, like spending a lot of time in the field (Rashid et al., 2015).

Therefore, I have used methods like field observations, interviews and user tests. I have made direct observations of real thrombosis procedures and simulation training, including several informal conversations about the work performed by practitioners at the department. Here, I have observed and recorded social interactions and practices in their natural work environment, mostly in the CT scan room where the thrombosis treatment and the simulated training take place.

Data about the thrombosis procedure, the practice and the prototype were gathered using various data collection methods. By performing document analysis of the standard operating procedure, I gained further insight in the canonical work descriptions for thrombosis. Interviews with the management and the practitioners at the department of neurology were performed to gain insight about the performance of clinical work and the importance of developing a new training method for the practitioners. Also, interviews of representatives at Attensi uncovered the process of developing virtual training applications. Later, I performed user tests where I observed how participants interacted with the prototype. After, they performed interviews, where I inquired about how the prototype represented their work as a practitioners of the thrombosis treatment. Data were captured through detailed field notes, handmade sketches made during thrombosis and simulation training, audio and video recordings.

These methods were used to 1) collect information about practitioners' activities and behaviour, and 2) to build an in-depth picture of the case, which according to Creswell (2012) are important for directing my attention towards the preferred data I need to best answer my research questions (Creswell, 2012).

3.1 Field observations

I have throughout this study performed field observations, gathering data about the clinical practitioners, their interactions with each other and the environment, and their conversations and activities in the CT scan and observation room. Through first-hand field observations, I gathered information about the workplace's social processes within these processes' natural context (Silverman, 2001).

I observed how workers interacted with each other in their natural setting, outside specific procedures in the emergency ward. This shed light on the nature of the practices at the department of neurology. As I did not have knowledge of the different professions at the department, it proved challenging to identify the specific professions to which each practitioner that interacted with each other were a part of. Therefore, I mostly observed residents and senior doctors at their post in the emergency ward.

3.1.1 Observation of thrombosis procedure

I made observations of two thrombosis procedures, monitoring both practitioners engaged with treating the patient in the CT scan room, and the waiting practitioners in the observation room. As illustrated in figure 3.1, I registered several informal conversations between co-workers, and how the working team collaborated and coordinated the procedure. I did not interfere with the work that was being performed, rather I took the role of what Creswell (2012) referred to as "non-participant/observer as participant" (Creswell, 2012); I did not have a direct impact on the procedure, but observed and recorded the procedure from inside the CT observation room. All findings which I found to be of importance to my study was recorded using handwritten notes and sketches.

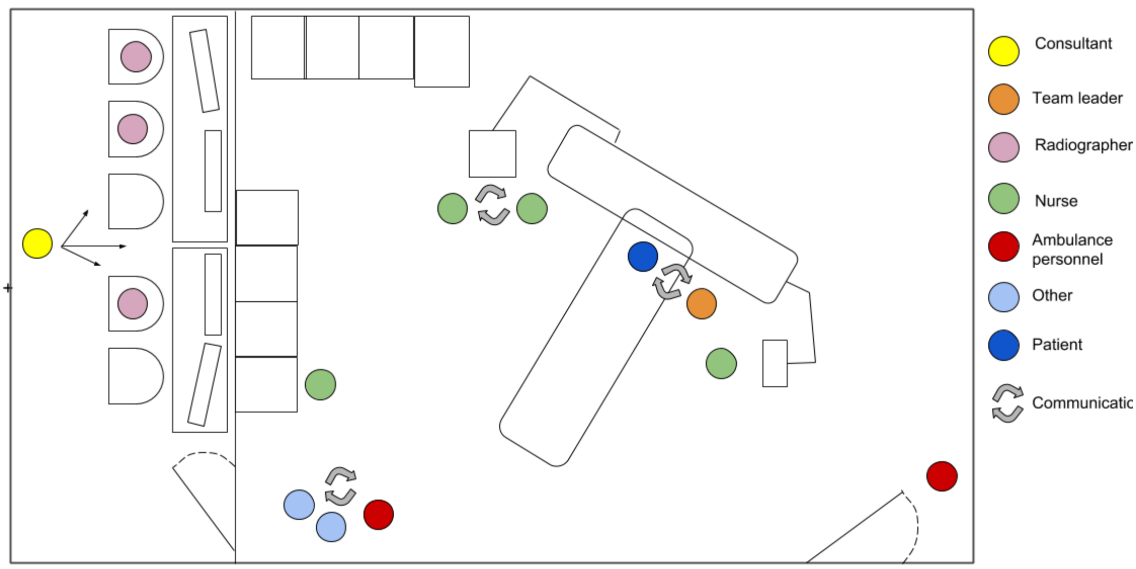

Figure 3.1: Practitioners interacting with each other and the environment during a thrombosis treatment.

More observations would have been beneficial to collect more reliable data. However, as explained by several practitioners, the number of incoming patients with presumed thrombosis varies from day to day and cannot be planned.

3.1.2 Observation of simulation training

I gained further insight into the practitioners' current training methods by observing the simulation training in the CT scan room. I recorded how the team performed the work responsibilities described in the standard operating procedure, and how they trained on performing necessary collaborative skills.

I only made formal introductions with the senior doctors observing the simulation, the resident and the radiologist in the CT observation room. It is however uncertain if all team members, like the acute nurses, were aware of being observed. According to Silverman (2001), my presence could be perceived as intruding, further having the potential to change the behaviour of the practitioners being observed (Silverman, 2001, p. 58). However, as the working team members in the CT scan room are frequently being monitored from the CT observation room by other team members and the management at the department, being observed is something they probably are used to and may not have had an impact on their performance.

3.1.3 Data gathering and recording

The field observations were recorded using various techniques. During the direct observations of the thrombosis treatment, detailed field notes and hand-drawn sketches were made using pen and paper. These were after each session written into a more detailed and elaborated versions. Hand-drawn sketches were used as a supplement to the taking of notes, visualising and enhancing my understanding of the cooperative setting in the CT scan room. Notes were also used to capture the informal conversations made between senior doctors, residents and nurses.

Data were captured without directly engaging the practitioners, as the focus of the observations was on the actual activities being performed by the team members, not their subjective opinion of (Silverman, 2001). More subjective data were however captured through informal conversations with practitioners, giving me further insights into the practitioners view of their own performance, and a more holistic view of the procedure. As opposed to interviewing the practitioners about their behaviour, these informal conversations are important sources of data, and will yield a more accurate understanding of human behaviour and their interaction with the environment (Kvale et al., 2015). These conversations took place in the CT observation room, both during and after observed thrombosis treatment, and after simulation training. Further, as clinical practitioners often are preoccupied (e.g. with their patient rounds), conversations were also performed in the hallway between the CT scan room, the emergency ward, the offices and the cafeteria at ØHT.

3.1.4 Analysing data

As previously explained, recorded data were first captured using written notes and sketches. These notes were then documented in a more elaborated versions. These where later analysed, where I determined the most relevant findings in respect to the theoretical framework of this thesis.

3.2 Interviews

Two sets of interviews have been performed during this study. The first set included the interviewing of the management from the department of neurology, inquiring about the thrombosis procedure. I also interviewed the developers at Attensi. Secondly, several interviews were performed with the practitioners at the department during the user test of the prototype. I approached the process of performing the interviews using Kvale et al.'s (2015) seven stages of qualitative interviews as guidelines (Kvale et al., 2015), mainly focusing on the stages 1) planning and design, 2) performing the interview, and 3) transcription and analysis.

3.2.1 Interviews with management and developers

Planning and design

Planning and designing made the process of performing the interviews more systematic, all the while staying focused and making it easier to acquire the information I needed to answer my research questions. This phase involved identifying relevant interviewees, and developing interview guides.

I performed four interviews with representatives from the management at ØHT and the developers at Attensi. At ØHT, the head of department at neurology and project manager for digital training and simulation were interviewed. At Attensi, I interviewed the project manager and a senior developer.

Different interview guides were created with respect to the overall theme and the work each representative are performing. This guide helped structure the course of each interview (Kvale et al., 2015). These were designed as semi-structured interviews containing open and closed questions.

Performing the interview

Rather than function as a rigid script, the interview guides were used to give direction to the interview process. This gave me moderate control over the themes I wanted to cover, while still being able to ask open questions which generated rich and individual data, resulting in a deeper understanding of the inquiry (Rogers et al., 2011). The interviews started with an introduction where I explained the purpose of the interview and gave an overview of the general themes I wanted to cover.

At ØHT, the head of department and the project manager were interviewed regarding the thrombosis procedure. I made inquiries about their expectations of having the VS function as a training tool after deploying the finished application at the department. Further, I asked about their previous experience with virtualization technologies and the collaboration with Attensi. The interview with the head of department took place in a calm and undisturbed environment at the hospital. The interview with the project manager were performed in an empty classroom at Østfold University College. It should be noted that the head of department and the project manager had already read my special topic assignment - a paper written at the start of the semester covering much of the relevant literature used in this thesis. Conducting the same interview without them reading the assignment may have resulted in different findings, as they by reading it gained knowledge regarding the thesis' theme and theoretical position.

Interviews with the project manager and the senior developer took place at Attensi headquarters in Oslo, and inquired about the process of developing the prototype of a virtual task trainer, issues and past experiences with development of training applications.

3.2.2 Interviews with practitioners

Planning and design

Interviewing the practitioners were planned alongside the preparations for the user tests at ØHT, as these tests provided the basis for discussing the practitioners' experience with the prototype.

One interview guide was created for all the participants, so that each individual answer could be examined and compared. The guide were created as a semi-structured interview, containing both open-ended and closed questions, inquiring about behaviour, reflection and apprehension of a prototype which could be used as a tool supporting their every-day, clinical practice. The open-ended questions were used to gain information about how participants perceived the prototype. The closed questions inquired about general information regarding participants' background, which often were elaborated with a follow-up, open-ended question.

The interview guide inquired about general first impression and their experience when using the prototype, but also how the prototype supported their work description and how it was to use the application as opposed to regular simulation training in the CT scan room.

In total, seven practitioners were chosen to partake in the interview and user test, including five residents and two senior doctors. Acting gatekeeper, head of department, helped identify practitioners with executive time that could participate, find location and time for the interviews and user tests.

Performing the interviews

The interviews were conducted as a one-on-one interview in the offices for neurological senior doctors at the hospital. As reserved and uneasy participants may be reluctant to share information, it was important to create a safe interview environment and make the participant feel comfortable (Creswell, 2012). Therefore, each interview started of casually, with me levelly seated facing the participant (see figure 3.2). I introduced the project, explaining the purpose of the interview. Handing out a consent form, I explained how I intended to capture information, and that their statements anonymously could be used in scientific publications. As these interviews were performed alongside the user tests, a more detailed description of the setting is given in section 3.3.2.

The interviews were performed in two rounds; after the participants first and second use of the prototype. While the first round inquired about their first impression, the second round focused on capturing their in-depth impression of the application, and their individual and subjective thoughts on how it reflected the practice of performing a thrombosis treatment.

During the first round of interviews, it became clear that some participants already had used the prototype. Therefore, the question inquiring about the practitioners' first impression of the prototype was not accurately comparable, as these participants were more familiarized with the prototype. However, I was able to alter the question, making them recall and explain their first encounter with the prototype.

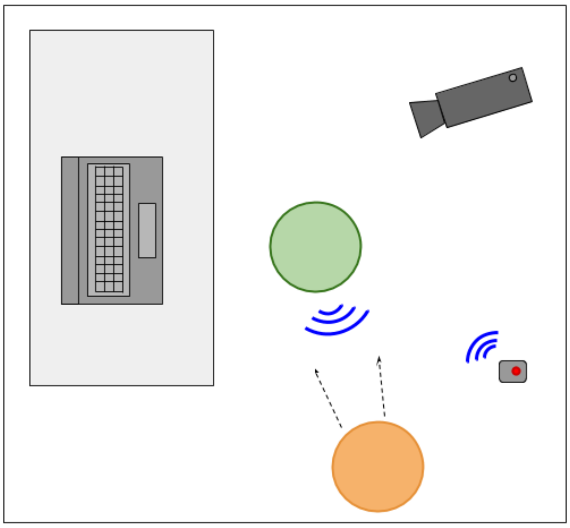

Figure 3.2: Conducting the interview between and after user test.

At the end of the interviews, probing questions were used to make the participants describe their experience with the prototype or other aspect of the project, by e.g. asking whether the participants had anything more to add (Rogers et al., 2011).

3.2.3 Recording and transcribing

Every interview was captured using an audio recorder. Later, each audio file was transcribed, readying it for further analysis (Kvale et al., 2015). Although the process of transcribing audio can be time-consuming, recoding the interview let me pay more attention to the interviewees' answers during the actual interview, enabling me to ask more relevant follow-up questions. Hand-written notes were made, complimenting the audio recordings.

Audio recordings of an interview is beneficial when wanting to capture research data. However, I needed to be aware of the loss of information occurring when transferring the interviewees statements between 1) direct communication, 2) audio playback of this communication and 3) documentation of interview through written transcription. Silverman (2001) explains that gathering an authentic understanding of the subject under study is challenging when performing qualitative research (Silverman, 2001). Kvale et al. (2015) further argue that transcriptions are abstractions of the spoken language, and that elements like gestures, and tone of voice are lost (Kvale et al., 2015). As it is, the transcription of a spoken conversation is a "decomposed rendition" of the interview (ibid, p. 205). Although researchers often commented on statements inside the transcription based on memory and notes, it may have an impact on the credibility of the final result. It is a process of interpretation, making it important to not make assumption about each statement, rather document them as objective as possible, with a clear distinction between the data and the interpretation, making the results more credible (Silverman, 2001).

3.2.4 Analysing data

Performing a systematic analysis are according to Silverman (2001) an important criteria for the credibility of the result (Silverman, 2001). When analysing the different transcriptions, I performed qualitative coding - a common method for data analysis which categorizes the interview statements (Kvale et al., 2015). By coding the data, I gained further understanding of the findings. According to Kvale et al. (2015), breaking each transcription down and categorise it can make the data easier to manage and compare. During the analysis of each transcription, I started to manually color code the paragraphs using a set of determined categories. These categories are presented in table 3.1 and 3.2.

Categories from management and developers
Facts
Issues
Worth
Cost
Development
Practice and situated action
Technological aspects
Future work
Quote
Implementation

Table 3.1: Categories from management and developers for analysing findings.

Categories from participants
Transferrability (to reality)
Quote
Discussion
Collaboration
Deviations from clinical practice
Awareness

Table 3.2: Categories from participants for analysing findings.

Several categories were chosen for their relevance regarding the theoretical framework, like collaboration, deviations and awareness. Others emerged later in the analysis based on the common themes in the answers given by the interviewees, including development, issues and facts.

Later, each paragraph was analysed and transformed to more specific *meaning units*; a shortened version of the original text capturing the essentials from each segment (Kvale et al., 2015). These units were collected in a new document, were the units from each individual practitioner could be compared.

Lastly, the segments of collected meaning units were further analysed in respect to the themes and the research questions, and the most important findings from the interviews were written together in descriptive statements. According to Kvale et al. (2015), this type of analysis helps to focus on the natural meaning behind each answer and its relevance to the inquiry.

3.3 User tests

3.3.1 Planning and design

The user tests were planned and designed alongside the interviews of the practitioners at the hospital. Given the busy nature of medical work, I depended on the assistance of the head of department to find practitioners and set up the sessions.

3.3.2 Performing the user tests

Seven practitioners participated in the user test, which were the same that partook in the interviews. The residents, five in total, participated in the test on January 23. The two remaining senior doctors participated on February 8. The user tests were performed in the shared office of the senior doctors at the department of neurology. Except for two interferences where senior doctors that had already participated in the test came back into the office to work at their station, the performance of the user tests were otherwise uninterrupted. The users were seated in front of the laptop, with the video camera capturing audiovisual information about the users' on-screen activities (see figure 3.3).

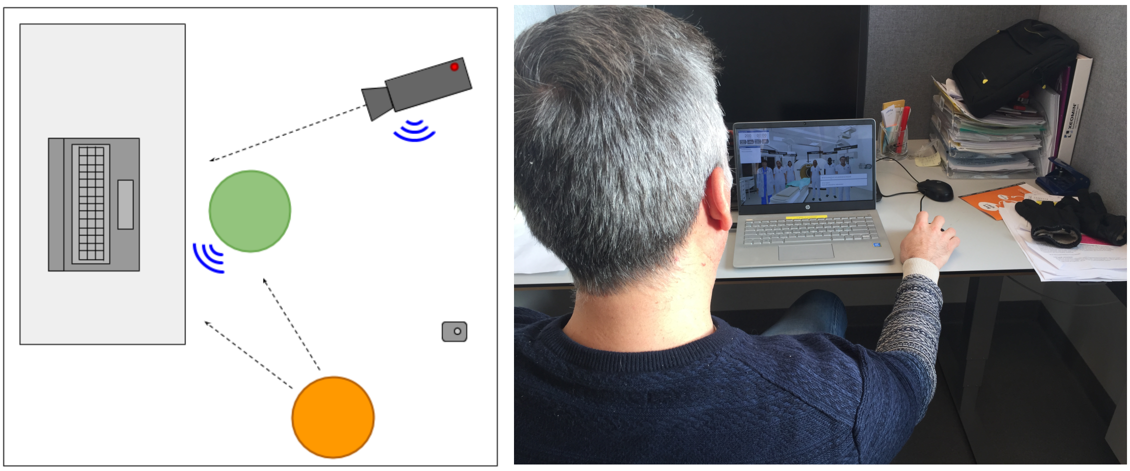

Figure 3.3: Left: The setting of the user tests. Right: A senior doctor testing the prototype.

As I wanted to capture a honest reactions from how the participants perceived the prototype, I did not interfere or answer questions related to the prototype. However, I did intervene when participants experienced bugs and breakdowns, which occurred as a result of an error in the prototype's code. Several participants experienced this breakdown, which may have influenced their perception of the prototype and its potential as a training application. As they were not able to finish the particular playthrough in which the breakdown occurred, it may have influenced their answers during the interviews.

3.3.3 Data gathering and recording

I captured data using written notes and video recordings. Photographs taken using a smartphone illustrated the user tests, and were complimentary to hand-drawn sketches. Video recordings captured audiovisual, detailed information about participants interaction with the prototype, and was set in a fixed position behind the participants. As this type of recording can seem intrusive, the camera position was supposed to make the participant feel more relaxed, as it did not directly capture his or her facial features. The camera recorded sound, and the participants were asked to comment on their experience throughout the test, capturing users' situated thoughts and feelings. Asking them to speak out loud resembled the think-aloud protocol, a technique that is useful for understanding what the participants are thinking and trying to do when interacting with the prototype, externalizing their thought process (Rogers et al., 2011). The protocol was however not performed systematically, as several participants seemed reluctant to speak out loud.

3.3.4 Analysing data

Analysing the video records from the user test captured both qualitative and quantitative information. The qualitative data included the registration of how they used the prototype, their course of action and their comments. For quantitative data I also captured the number of successfully completed tasks, point scores and the time used to complete the simulation. However, using these quantitative data to gain further understanding of how the prototype was perceived would not yield reliable results, as there are too few participants to perform credible statistical analysis. Also, during the analysis it became clear that the different choices the users can make throughout the prototype results in different end-scores. The number of choices also varies, as dialogue options either leads to fewer or more dialogue choices.

Through video analysis, it was easier to register which of the actions performed by the participants that lead to breakdowns of the prototype. However, the data from the video analysis were mostly used as complementary findings to the interviews.

When analysing the results from both user test and interviews, I kept in mind the challenge of proving the reliability of the results, as there are no standard application, i.e. no similar hospital that has performed the same study, to compare my result with.

3.4 Ethics

As stated in subsection 3.2.3, being as objective as possible, making the distinction between the data and the interpretation of the data clear, is important for the credibility of the result (Silverman, 2001). This is also important for the ethical aspects of the research. Striving for objectivity, the researcher tries to avoid influencing the results from the study based on his or her personal values. Silverman (2001) explains that the results from a study are often directed and biased by the researcher, making objectivity important throughout the entire research process.

Further, he explains the importance of 'informed consent', informing the participants of the researchers presence and intentions with the study. Interviewees and participants of the user tests therefore signed a consent form which explained the purpose of study and the participants' anonymity, where they further consented to the gathering of data using tape recordings and the intended use of that data.

However, during the course of this study there were times were employees at the hospital were not presented with consent forms or knew that they were being the subject of a research inquiry, like during the field observations of thrombosis and simulation training.

According to Silverman (2001), this type of ‘covert observation’ can lead to ethical problems concerning ‘informed consent’ (ibid, p. 55). Nonetheless, the gathering of personal and sensitive information about employees were not the purpose of this study. Rather, I captured human behaviour and collaborative attributes in the CT scan room. When it comes to these types of ethical dilemmas, Silverman (2001) explains that ‘covert’ access do not always involve ethical offences, as long as the research is ”reasonably sensible” (ibid, p. 55). Also, I had received what he referred to as ”consent by proxy” (ibid, p. 271); acting gatekeeper the head of department consented to my presence and the capturing of data in the emergency ward, further reducing ethical issues with the study.

Another ethical issue that needed to be addressed was the fact that my study revolved around medical patients. Although no attempts were made to gather sensitive data about patients, doing field recordings in a setting which includes patients gave rise to an ethical dilemma; I cannot assume that my presence during the procedures did not feel offensive to the patients. Given the sensitive nature of this study, no tape-recordings were made during field observations. Instead, I relied on detailed field notes and sketches.

Further, I consulted the field’s professional associated ethical guidelines, which according to Silverman (2001) can help clarify ethical issues. An application was therefore sent to REK (Regional Committee for Medical and Health Research Ethics) and NSD (the Norwegian Centre for Research Data). They approved the application given that all collected data were regulated by the Personal Data Act § 31. The research findings presented throughout this thesis are therefore mediated based on ethical principles regarding the privacy policy of participants, and also ethics in patients and medical care.

Chapter 4

Results

I here present the results from the data collection and analysis process described in chapter 3. In sub-chapter 4.1, I present the findings regarding RQ1 - how, according to the practitioners, a prototype mainly developed using the standardized procedure plan represent the work they perform during a thrombosis treatment. In sub-chapter 4.2, I address what indications the gathered data give for the inquiries made in RQ2, presenting how this study has shed light on the 1) training of practitioners involved with the treatment, and 2) ongoing articulation work at the emergency ward.

4.1 The prototype representing thrombosis treatment as performed by practitioners

RQ1: How, according to clinical practitioners, do a prototype of a virtually simulated task trainer, mainly developed using a standardized procedure plan, represent thrombosis treatment as practised by teams responsible for this treatment at ØHT?

After participating in the user test of the prototype, participants were positive to the concept of using virtualization for clinical task training. Although they felt that the character animations where hard to interpret, they found the graphical appearance of the prototype to accurately represent the clinical environment at the hospital. Participants also found the simulation valuable, as it made them more aware of the other members of the team. One participant expressed that being able to reflect on one's own work activities, and the work performed by the other team members, in a calm environment, were valuable (# 1).

However, there were different opinions regarding the prototypes ability to accurately represent work responsibilities. Several found that there was too much focus on keeping track of the virtual team members, neglecting the responsibilities of a resident or senior doctor. When it comes to articulation - whether the prototype supports necessary articulation attributes - the participants explained how the virtual performance did not simulate the complexity of real life thrombosis procedure well. The artificially simulated collaboration did not support activities necessary for coordination and communication between co-workers, as the user are limited to an a one-way communication with the technological system, which in the field of HCI are defined as a instructing interaction type (Rogers et al., 2011). Also, coordination of work was described as difficult, unnatural and static, as the user is bound to clicking, inspecting and correcting virtual workers. One participant commented that the virtual workers "[...] are complete idiots. They roam around. I don't exactly know what they're doing. And when I click on them [...] it is hard to understand if they have done what they're supposed to" (# 4).

Some participants expressed that the VS could be a beneficial tool for training on the standardized procedure, with standardized positioning of the team members throughout the treatment. However, several participants expressed that the prototype was too strict, not supporting individual practice.

Some participants explained that the prototype neglected the work performed by the residents or senior doctors, as it was too focused on keeping track on the different team members; whose job it is to take off the patient's shoes is not worth that much attention (# 6). But, as one participant explained, being a team leader is different than stepping into the emergency room as a resident or senior doctor, where the patient is the main focus, further saying that he "[...] thinks the purpose that the game should serve is right. [...] The nurse should be able to position herself, [...] but as a team leader I must be able to correct minor deviations. I have not learned this at the University, but in the field" (# 7).

Most participants commented on the clinical examination (NIHSS). It was seen as unnatural and did not reflect a real examination. As one participant explained, "[...] the NIHSS is a standardized rating which can be done from A to B, [...] but if it during the examination becomes obvious that the patient is having a stroke, we don't need to use that much time on the rating" (# 6). Another participant also noted that if they can assume that the patient are having a stroke, it is more important to get the CT-scanning to clarify the assumptions, adding that "[...] this is not written in the protocol, but it is a practice that everybody follows" (# 3).

Deviating from the predetermined course of action in the prototype results in a negative score. Some participants expressed that this predetermination of action, e.g. that blood is to be sampled from a specific arm, made the prototype less genuine. One participant expressed wanting more unanticipated event, as this is common during a thrombosis performance (# 7).

By mainly using an instructing interaction type, the simulation did not support mutual awareness information about users, nor the mutual conversation needed in real thrombosis treatment. Here, co-workers are required to correct deviations, instruct one another and to make shared decisions.

Based on the answers from the practitioners participating in the user test, the prototype id not adequately represent the thrombosis treatment as performed by practitioners. However, participants recognized that what they had tested was a prototype, and expressed that further improvements can make the finished VS a valuable tool for training clinical practice and collaboration.

4.2 The prototype supporting training of practitioners and ongoing articulation work

RQ2: How do an evaluation of this prototype and clinical practices shed light on realistic virtual simulations for supporting 1) the training of practitioners and 2) ongoing articulation work within clinical teams?

This sub-chapter present the findings regarding the RQ2 of this thesis; training of practitioners and ongoing articulation work at the emergency ward. The former will be addressed in the section 4.2.1, presenting how evaluation of the prototype may shed light on the VS as a potential training application for practitioners in clinical teams. In section 4.2.2, I first address how the hospital's current thrombosis protocol is a result of a longer articulation work process performed by the management at the department. Lastly, I present how practitioners engage in articulation work during thrombosis treatment, and how the prototype reflects this work.

4.2.1 Training medical practitioners

Interviews revealed how the management at ØHT want a virtual task trainer, giving practitioners a training method that "converge" the standardized protocol and clinical performance of thrombosis treatment. Today, practitioners learn about their work by performing or observing thrombosis treatment, through formal education, and participation in simulation training.

Head of department explained that it is not the reading or observation of a procedure that makes a good clinician. Nor is it performing well during formal education. Increased knowledge and the quality of work performance are a result of training, where the treating of patients and performing debriefings generate experience. Based on this assumption, he wants a training method that can complement traditional training methods, e.g. reading. He hopes that by using a VS, where each work activity is perfectly simulated, the overall effort of mediating and coordinating work are reduced.

During the user tests and interviews, several practitioners reveal that they already possess knowledge about the canonical description of the procedure. However, the biggest problem with today's thrombosis treatment is that each worker is performing individual practice, deviating from the most efficient way of performing the treatment collaboratively. The project manager at ØHT explained that it is not specific things that the practitioners do that deviates from the formal plan, rather it is small deviations throughout the entire procedure, which have a negative effect on the treatment time. Therefore, the hospital wants a tool that mediates the most efficient routine to the practitioners, further using a VS to generate experience with the procedure.

Today, the alternative training method is simulation training in the CT scan room. Head of department explained that conducting a full scale simulation training costs 130-150 000 Norwegian kroner. Therefore, this has only been performed once since the hospital opened in 2015. This simulation was mostly done to test the procedure in the new hospital layout at Kalnes, not for the training of employees. On a smaller scale, simulation training is performed up till two times each month. However, the head of department explained that these cannot replace continuous or extensive training. Teaching the procedure to the practitioners involves having a senior doctor observe the simulation trainings and perform debriefings. This is therefore only possible if 1) a senior doctor has time to observe, and 2) if thrombosis team has time to receive a debriefing. Further, there are many practitioner involved with the thrombosis procedure at the department, and simulation training can not adequately train all of them. Also, due to the high turnover at the department, practitioners do not receive the training required to obtain sufficient knowledge of the treatment. Having a training tool that visualizes the procedure without being time-, team- or location-dependent, is valuable.

By using a VS that gives rapid, visual feedback about the procedure and on how the user can improve his or her performance, the head of department hopes to trigger the participants' ability to reflect on the treatment. In addition to being a method for reflection, the project manager at ØHT explained that it is more to such a project than just the finished application; the entire project may shed new light on the thrombosis treatment, opening up a discussion about the procedure. This can have great value, and may contribute to further adjusting the team members' individual practices.

After the last collaboration between ØHT and Attensi, practitioners at the hospital were mostly positive to using virtual training applications. Many explained how interacting with a virtual application was more beneficial than watching a video or reading a text. According to the project manager at Attensi, previous projects have seen a clear correlation between the usage of digital competence applications and organizational change. She explained that workers find this type of training entertaining and are often reusing the application, resulting in increased knowledge of tasks and routines. As an example, she explained that summer substitutes using training applications before starting in the new job will learn their responsibilities at a faster rate than workers only given standard training.

When interviewing the participants after the user tests, they expressed finding the prototype valuable as a practical training tool. After further development, a VS may be a more beneficial tool for training than e.g. reading. Although one participant explained that the best would be to perform an actual thrombosis (# 4), several expressed that the VS could be valuable as a training tool for novices. It can prepare the practitioner for a real thrombosis, as he or she can observe and interact with the process.

Most participants agreed that a VS could improve collaboration is the CT scan room (# 1-6). One participant explained however that one can not use a training tool to become a team member (# 7). He considered collaboration as highly individual which requires complex social skills. This, he explained, is only learned through field experience.

4.2.2 The prototype supporting ongoing articulation work

Findings from this study shed light on two different levels of articulation work regarding the thrombosis treatment; the management's process of managing the procedure and articulation work performed by practitioners during treatment.

First, I address how the management at the hospital engage in articulation work as an ongoing process happening in the "background" of the everyday clinical work, evolving and optimising the operating procedure. Lastly, I present findings regarding the articulation work performed by the practitioners during a thrombosis treatments.

Organizational articulation process at ØHT

The standard operating procedure describes the sequential performance of thrombosis treatment, presenting formal rules dictating whether the incoming patient is a relevant thrombosis candidate and how a relevant candidate is to be received and treated. This document is a result of an ongoing articulation process performed by the management at the department of neurology, and are currently the most updated version of the procedure.

Interviews with the head of department explained how thrombosis treatment is a relative new procedure, first approved in 1998 after the Safe Implementation of Thrombosis in Stroke-Monitoring Study (SITS-MOST). Since then, hospital management has continued to optimize the thrombosis protocol, leading to decreased treatment time. Compared to national numbers, the significant low survival rate in Østfold motivated to further examination of the process. He explained that thrombosis treatment is continuous quality work, and that the goal in this ongoing process is to decrease treatment time for each procedural step that is to be performed. The management has also used a tabletop simulation in the form of an A3 sketch of the CT scan room, using board game chips to simulate team members' position during the procedure. Other sketches have also been made to discuss and reflect on procedure. The department has also performed a full scale simulation training, with a total of 15-20 practitioner involved with performing the procedure and participating in a debriefing. The main goal was not to train practitioners, but to test the procedure in the hospital after it opened in 2015.

The management at ØHT have used the thrombosis protocol, A3 sketches and simulation training to reflect and discuss recently completed treatments, further improving the protocol. This articulation process has yielded positive results; In 2004/5, the average thrombosis treatment time was 60 minutes. Today, the average treatment time is reduced to 30 minutes. Head of department hopes to further reduce the average time to 20 minutes.

Articulation work in practice

Although many participants found the prototype valuable as they learned about team member activities, the coordination of the team was seen as too strict and unnatural, not reflecting team leader's clinical practice.

Attensi has developed a suggestion to how a prototype of a VS can support the team leader of a thrombosis treatment. This prototype is developed mainly using the standard procedure. According to the project manager at Attensi, the team leader must have explicit knowledge of the work performed by practitioners from different professions during thrombosis treatment. He or she must be able to correct deviations made by the team members, as these deviations will have a negative impact on the performance of the rest of the team. She explained that by having an explicit understanding of possible actions, and how these actions will influence corresponding activities, will make it is easier to manage larger deviations.

During field observations, various practitioners explained the importance of having a clear understanding of the work that is to be performed, and that a more disciplined performance may save valuable time. Practitioners must know when they're needed and when to step back to make room for the work that is to be performed by other members. As seen during field observation, practitioners coordinated activities by engaging in different forms of communication. This included 1) informing co-workers about current or finished tasks, 2) negotiating the most beneficial course of action, and 3) engaging in shared decision making. The collaborative practitioners did also perform various articulation activities to accommodate for deviations. These deviations could be small, like adjusting cooperative activities if the nurse needed change the arm for blood sampling. However, when faced with larger deviation, practitioners showed uncertainties about work responsibilities, leading to breakdowns in communication and coordination, also between other departments at the hospital.

In the prototype of the VS, users are presented with different articulation activities, including prioritizing work activities, creating check-list and coordinating the virtual team. Of these objectives, prioritizing and creating check-list were the easiest to perform. However, participants expressed wanting more options for both failure and success. Further, they wanted more scenarios, training on contingency management. This corresponds with the head of department's wish for randomized scenarios; each patient is unique, and the practitioners should training on different situations.

Chapter 5

Discussion

When investigating how a virtual training application can optimize the treatment of patients with presumed thrombosis I have asked myself whether designing and deploying a training method promoting standardized work are done at the expense of the complex, collaborative practice being performed in the CT scan room. Further, what are the requirements when developing a virtual training application beyond that of virtualizing the standard operating procedure? Also, how can a VS complement the training methods currently used by the practitioners at the department?

In this chapter, I will first discuss the research findings in regards to the theoretical framework used in this thesis. In sub-chapter 5.1, I discuss the current training methods for thrombosis treatment at ØHT, and how a VS can be used as a training tool by the practitioners involved in this treatment. In sub-chapter 5.2, I discuss how the findings reflect theories about the articulation work performed during thrombosis treatment. Then, I address what the findings imply for the use of a VS as a coordination mechanism for the practitioners, how the VS represents the work as performed by the practitioners in the department.

In sub-chapter 5.3, I discuss how the findings from this study have shed light on implications for development and design, including design tensions and different types of virtual representation. Lastly, I discuss recommendations for future development of the prototype, addressing awareness support, situated action and considerations for implementation.

5.1 The VS and practice learning

Here, I discuss the interplay between the results from RQ1 - how the participants perceived the prototype - and the first sub-question from RQ2, training the practitioners responsible for the thrombosis treatment.

5.1.1 Training for thrombosis treatment at ØHT

Today, practitioners learn about the treatment through formal education, the occasional simulation training and during the performance of actual thrombosis treatment.

According to a recently graduated informant from the user test, learning about the thrombosis treatment during the formal education included a written curriculum and mandatory on-line videos of the clinical examination (# 3). The head of the department explained that reading as an isolated measure won't give the personnel the training or experience that is required to improve the performance of thrombosis treatment.

ØHT therefore arranges physical simulation training every other Friday. According to Nestel et al. (2017), role-playing simulation has long been used in healthcare training, and have proven to be a beneficial technique for training medical personnel (Nestel et al., 2017). They explain how simulation training has a positive impact on learning and the performance of medical work, further promoting teamwork during procedures. This training leads to changing clinicians behaviour and attitude towards safety, perception of clinical decision-making and can improve patient outcome.

The problem with simulation training at ØHT, is that it requires considerable resources. The hospital do not have a training facility, so simulation training takes place in the emergency ward. This means having to reserve the CT scan room, hoping not to be discontinued by incoming patients. Further, a member of each clinical profession must be present, and workers have to be taken out of active duty. The head of department explained that simulation training has potential, but coordinating it is a challenge, where the result is that many practitioners at the department have not yet participated in this form of training.

In addition to knowledge gained during formal education and simulation training, practitioners train on their respective work by performing thrombosis treatment. They learn how to function in a community of practice (Lave and Wenger, 1998; Gherardi and Nicolini, 2002; Brown and Duguid, 1991). Brown and Duguid (1991) explain that through workplace learning, individual workers forms or joins these communities, and that learning is more about becoming a practitioner rather than learning about the practice (Brown and Duguid, 1991). By being a part of this community, workers form an identity respective of that community (Lave and Wenger, 1998). The workers learn the formal and informal rules of the workplace from members of their own profession (where to stand, how to communicate and when it is appropriate to interfere). For instance, a recently graduated nurse will learn how to function in the thrombosis treatment from another more experienced nurse. In the thrombosis treatment, this form of practice learning is also shared between interconnected communities (Gherardi and Nicolini, 2002), where nurses, radiologists, residents and senior doctors are all part of a network of communities of practice. They learn how to bridge the gap between 1) the formal, canonical descriptions as taught by the senior doctors, the written curriculum and the simulation training, and 2) the non-canonical workplace practice.

The management at the department of neurology want a training tool that can compliment the current training methods for thrombosis treatment. They find it important to visualize the procedure, giving the practitioners a training tool which triggers reflection and gives visual feedback. However, until the VS is deployed as a training tool for the workers involved with thrombosis treatment, the practitioners are mainly learning about the work they are to perform through the community of practice at the department. It will be interesting to see how the new training tool, which are currently focused on mediating the standardized procedure, will be used by the individual practitioner and integrated into the interconnected communities. Will the practitioners find the VS obtrusive as it somehow interferes with the community of practice and individual identities?

On the other hand, thrombosis treatment is a relatively new procedure which, as a result of the continuous quality work to decrease treatment time, has seen several adjustments. The practitioners may be accustomed to rapid changes of the standardized procedure. Also, due to the high turnover of practitioners, a community of practice may not be as 'incorporated' in the department as it would be if the workplace consisted of the same practitioners for a longer period. Therefore, deploying the new training tool may not have a significant impact on the community.

Further, the head of department explained that it is among other things the demanding and unexpected nature of the work that is the reason for the high turnover. A training method helping to standardizes the work may give novices clearer guidelines, making the procedure seem less overwhelming and vague, which have the potential to decreased the turnover rate at the department.

5.1.2 Training practitioners using a VS

Stokowski (2013) suggests that a VS can compliment traditional classroom learning, preparing the students for clinical work by bridging the gap between theory and practice (Stokowski, 2013). In a similar way, can a VS help bridge the gap between canonical and non-canonical work of the thrombosis treatment?

During the user tests, the participants were positive to the prototype's 3D environment, as it accurately represented the work environment they have come to know through their work at ØHT. Participants recognized the CT scan room and work equipment, making the scene seem familiar. However, participants seemed conflicted when asked how the prototype mediated the procedure. One informant explained that he thought Attensi had done a good job at creating an environment that looked realistic, however "[...] it requires some adjustments to make it [the procedure] seem familiar" (# 6). Most described it as too rigid to represent the situated performance of a thrombosis treatment.

Participants had different opinions regarding whether the prototype accurately represented the work responsibilities and the practice of performing a thrombosis treatment. One could argue that it is because the prototype is mainly developed using the standardized procedure, and do not yet represent individual practice or contingencies.

However, one should also consider the practitioners definition of 'accurate responsibilities'. Their answer is a result of their previous experience with simulation training and performance of real thrombosis treatment, which are highly situated. If each thrombosis treatment is different, practitioners will form an understand of the procedure based on individual experiences. This became evident during the interviews with the practitioners, as different residents had different opinions about the procedure. Some said that the clinical examination had to be performed after preparing the patient (e.g. after sampling blood), so as not to delay the work of other team members. Others said that one could start performing the examination earlier in the treatment. Many of the comments made by the participants, not including those regarding the casuistic errors and technological issues, are related to the situated nature of performing a medical procedure. This may the a result of their previous training methods, which has either been the observation of or participation in situated performance of a thrombosis treatment. So even when employees learn to become practitioners through the interconnected communities at the department, where individual employees are taught the formal and informal rules of the workplace from more experiences co-workers, their opinion of the thrombosis treatment is bound by the highly situated environment in which they work. Therefore, without a standardized training method the formation of individual practices may be inevitable.

Although each worker has formed an individual understanding of the thrombosis procedure, the interviews revealed that they (at least in theory) also have knowledge of the canonical description of the treatment. For example, when the user in the beginning of the prototype are called by the ambulance personnel, several participants commented on an error. The case presented in the prototype clearly states that the patient showed medical symptoms at 9 o'clock in the morning. The clock at the in-game computer screen shows that the time of the ambulance call was made at 14:15. For patients to be relevant thrombosis candidates, they must enter the hospital within a 4,5 hour window. Therefore, the virtual patient would not have been treated using this specific procedure. As one participant commented, "[...] if it [the stroke] happened at 09:15, and the time is 14:15 now, why would I even accept her as a thrombosis candidate?" (# 4). Several participants explained that this would have influenced and changed how they would have proceeded in a real procedure. During the interview with the project manager at ØHT, he explained that the purpose of the VS is not to learn the process, rather it is about tweaking each practitioner's impression of the process. He explained that the user of the VS "[..] already know the process. It is about optimizing the process, getting it perfect and as efficient as possible".

The outcome regarding what the practitioners will learn after using a VS is not something this study has been able to measure, as the VS is yet to be finalized and deployed at the hospital. Nonetheless, the prototype has revealed that it has potential for *indirectly* generate knowledge, as it has caused the participants to *reflect* on the performance of a thrombosis treatment. Today, the prototype has worked as a method triggering what Schön (2017) referred to as reflection-on-action (Schön, 2017), as the practitioner during and after using the prototype expressed thinking back and evaluating previous procedures. One informant explained that she "[...] was more conscious [about the distribution of activities]. Because I have to admit that we focus a lot on what we are suppose to do, [trusting that] the other [professions] know their activities and make sure that these are performed" (# 1). Another commented that although she had observed the work of the different team members, she had not during thrombosis treatment performance or observation reflected on the work descriptions of the other workers. "So that was good to learn. [..] Even though I have seen it, and to some extent knows what they do, I became more observant [of the different activities]" (# 3).

Although some informants expressed that their experience with the prototype could prove valuable during their next thrombosis treatment, I have not been able to evaluate whether the VS will result in participants' reflection-in-action. Whether the VS has a more direct learning outcome will only be made visible after implementing the application into the everyday work of the practitioners.

It will also be interesting to see whether it have an impact on the collaborative teams reflexivity (Iedema, 2011), which is similar to that of Schön's (2017) reflection-in-action, except that where reflection-in-action regards reflection as an individual, internal process, reflexivity are a shared process where workers in close collaboration reflect and act collectively to solve situated work activities.

5.2 VS and articulation work

In this sub-chapter, I will discuss the ongoing articulation work performed during thrombosis treatment and the current coordination mechanism used in the department. Lastly, I discuss how the prototype of a VS can support the articulation of work during treatment.

5.2.1 Articulating the thrombosis treatment

Field observations and interviews with practitioners has throughout this study shed light on how these practitioners manage the collaboration of activities in their highly situated work environment.

During the debriefing sessions after the simulation training, the observing senior doctor explained how the practitioners sometimes are required to deviate from the standard procedure. In an informal conversation with the senior doctor after the training, she explained that the simulation training contributes to the standardization of clinical practice that is needed to decrease treatment time. She further explained that the training can also act as an arena where practitioners can discuss the best practice of performing a thrombosis treatment without risking patient's safety. Discussing contingent action is not the main purpose of the training, rather it is a side effect from practitioners questioning the procedure. As deviations are not something practitioners can safely practice, ØHT may consider implementing this into the simulation training. However, this will further add to the resources needed to coordinate the simulation training, which I in sub-chapter 5.1 presented as a challenge.

Observation of thrombosis treatment revealed how practitioners must be able to manage unforeseen events. If a team member must deviate from the current course of action, it will have spreading consequences throughout the procedure, making it necessary for all team members to re-coordinate work. And even though it is important to be able to manage these microcontingencies in relatively 'normal' thrombosis procedures, it becomes especially important in cases where larger contingencies force the team to further deviate from the standardized procedure. During the field observation of the so-called wake up stroke, it became evident that inadequate articulation of work responsibilities branched through the entire performance of the treatment. During the treatment, the patient was taken down to the MRI-waiting room as there currently was another patient undergoing the scan. After some waiting, it became clear that the MRI technicians were unaware of the waiting thrombosis patient. When faced with serious deviation, practitioners showed uncertainties about the coordination of work, which lead to insufficient articulation of work. This resulted in breakdowns in communication and coordination, also between other departments within the hospital.

These macro- and microcontingencies make the formal procedure plan inadequate, as the situated nature of collaborative work makes it necessary for the practitioners to improvise (Suchman, 1987; Schmidt and Simonee, 1996). As a coordination mechanism, the standard operating procedure tends to be underspecified, making "situated interpretations and improvisation" unavoidable (Schmidt and Simonee, 1996, p. 34). Further, collaborative practitioners use a complex set of awareness cues to communicate and negotiating the course of action (Bardram and Hansen, 2010). Observing thrombosis treatment shed light on how the workers need complex social skills as well as knowledge or the procedure. Practitioners were constantly seeking or supplying others with awareness information, all to best align their own activities according to ongoing events. These cues helped the practitioners manage the situated nature of the procedure, but also its *interdependency*, where workers positively relied on each other's timeliness to fulfill individual tasks (Schmidt and Bannon, 1992). This interdependent nature became clear when observing thrombosis treatment. Also, in the interview with the project manager at Attensi, she explained that because of the mutually dependent nature of the thrombosis treatment, everybody involved must be equally trained. She expressed that "if one person works, and the others are less effective, then it doesn't help".

Although often underspecified, plans and other forms of coordination mechanisms are still important for managing the distributed work within large organisations and workplaces like ØHT (Suchman, 1987). The management at the department of neurology is currently using coordination mechanisms to discuss and optimize the treatment. These mechanisms include the standard operating procedure, A3 sketches and mock-ups of the emergency ward and the CT scan room.

The standard operating procedure for thrombosis treatment are a coordination mechanism in its simplest of forms. It is a written document, containing important treatment steps, complications, contradictions and follow-ups. As a coordination *artifact*, it stipulates "general and situation-independent" information about the protocol (Schmidt and Simonee, 1996, p. 35). As a 'written record', it is abstracted and less contextualized than a real life thrombosis treatment. Referring to the work of Goody (1987), Schmidt and Simonee (1996) explain how language in it self is partly cut of from context as it uses less communication channels than e.g. face-to-face conversion (Goody, 1987; Schmidt and Simonee, 1996). Language in the form of speech in a co-present dialogue uses more communication channels than just the language in itself. Therefore, a written record do not take into consideration the complexity of practice, where collaborators use multiple channels and attributes to align work. However, as Schmidt and Simonee (1996) further argue, a written record (like the standard operating procedure) is in theory more accessible to the practitioners at the hospital, as it is taking the form of an artifact that is easy to distribute.

Where the operating procedure is a written record, the A3 sketches and mock-ups were developed to visualize the process and coordinate the collaborative workers throughout the thrombosis treatment. However, the procedure is not distributed to the practitioners as a coordination mechanism. Rather it, along with the A3 sketches and mock-ups, is used by the management to articulate the work of the practitioners performing the treatment.

5.2.2 The VS as a coordination mechanism for practitioners

The management at the department have now decided to have a virtual training tool developed for the practitioners. The VS can be described as a coordination mechanism, as it is going to function as a an artifact mediating the protocol through a proxy (Schmidt and Simonee, 1996). One could argue that the prototype is a high-fidelity, interactive representation of the work protocol, which purpose is to mediate the necessary steps of a thrombosis procedure. Seeing the VS as a coordination mechanism, it can be compared to other well established mechanisms.

Similar to the standard operating procedure, the VS can be used by a large number of people, as it is portable and not spatially constrained. However, the VS is more time consuming and less mobile than a written record. Nonetheless, as the standard operating procedure is not used in the training of the workers, giving them no previous preferences, the practitioners using the system may not find this problematic. Should the operating procedure be used for training after the implementation of the VS, the virtual application is still more dynamic and richer when it comes to representing multiple communication channels (Goody, 1987; Schmidt and Simonee, 1996). Even when using the written record as a guide, each individual worker must "produce and maintain the required dynamic representation of the state of the protocol with respect to the unfolding cooperative activities" (Schmidt and Simonee, 1996, p. 35). One of the informants from the user test explained that a VS helps the user by visually representing the procedure, and that "the brain uses less resources [..] as it [the simulation] has already constructed it [the visual representation]. And because the [virtual] environment is similar to the environment we work in [..], I think it is easier to understand what is going on" (# 7). The worth of the application may therefore exceed the cost of being less mobile.

5.2.3 VS and articulation work

Several participants expressed that for the VS to be an adequate training tool it has to be close to perfect, accurately simulating different workers and situations, giving room for deviations and alterations. The current prototype do not represent articulation of situated work well, as it is mainly derived from the formal, standardized procedure made by the management of the department. Given the comments from the participants, there seems to be a conflict between the management's wish to standardize the procedure, and the practitioners need for an application that respects its situated performance. As one participant from the user test noted, the prototype does not represent individual clinical practice – the situated nature of a thrombosis treatment being non-canonical work were practitioners must assess the individual patient and perform shared decision making with team members.

When it comes to accurately simulating work responsibilities, participants found that their routines were presented as illogical and unnaturally strict. The VS's predetermined course of action therefore negatively influences the VS's credibility as a correct representation of a thrombosis treatment. This corresponds with Suchman's (1987) notion of plans, explaining how these are sequential representations of tasks and predetermined events, and therefore have been criticized for being too rigid. One informant explained that a real life thrombosis treatment is much more complex than the step-by-step description in the protocol (#6). With this type of standardization, the practitioners get an impression of the crucial steps that need to be performed, but not the intricate nature of the procedure. As an example, several participant commented that the clinical examination must be presented better, as this is essentially the most important activity they perform (#2-7). This examination cannot be defined by, or confined to, a rigid list which is systemically checked - each and every patient is unique; some even shows obvious stroke signs, and therefore do not need to undergo the full examination.

Most participants found that there was too much focus on other team members tasks, and while familiarity with these activities may be beneficial, participants wanted the VS to be more focused on the responsibilities of a resident or senior doctor, e.g. more detailed simulation of the clinical examination. As several participant commented that the focus of the prototype did not fully represent the work they are doing as residents, one must question the degree of understanding the participants have regarding the differences with being a resident and being the team leader. One of the informant explained that the role of 'the doctor' is under-represented in the VS, therefore making it a bit boring (#7).

Nonetheless, as a team leader the practitioner must be able to monitor and correct other team members in addition to performing the responsibilities as a resident. The informant therefore found the VS to be valuable as a tool for training the team leader, but he could understand why the other informants found that the responsibilities of a resident was inadequately represented. This is a good argument for why this type of training tool is needed. Less experienced residents seem not to fully understand the distinction between performing thrombosis treatment as a doctor and as a team leader. This distinction should therefore be explicitly explained from the very beginning of the simulation.

Even though many participants expressed wanting less focus on the different team members in the VS, several expressed uncertainty about co-workers formal work descriptions. After using the VS, many stated that they became more conscious of their co-workers responsibilities. They were also able to reflect on the individual activities in a thrombosis treatment, something they normally can't do during the actual procedure given the urgent nature of the treatment. When asked how it was to experience thrombosis treatment training using a VS compared to the physical simulations in the CT scan room, one participant said that the VS is calmer than a real simulation, and "[...] you can sit down and think about your own role, and then you get a clearer perspective [of the procedure]" (#1). The participants reflected on the coordination of individual work activities in the collaborative setting, which they commented could lead to better discipline, better coordination, and to make the team more efficient. 6 out of 7 participants agreed that better insight in these activities can contribute to a better collaboration in the CT scan room. During the observation of the thrombosis procedure, a senior doctor expressed the importance of having a clear understanding of each team member's work activities so as to better coordinate and align one's own task accordingly. Dourish and Bly (1992) explain that awareness of the collaborating team members give context to one's own work (Dourish and Bly, 1992). By using a VS, awareness of virtual co-workers may contribute to increased understanding of 1) the work as performed by other team members, and 2) how one's own work corresponds, aligns and influences the entire collaborative process, which may lead to increased understanding of the work performed across the different professions involved in the treatment.

After using the prototype, one participant commented that "[...] it is also useful for dealing with contingencies. Knowing the work responsibilities - what people are waiting for, who's waiting on whom.. It's all about being fast" (#6). Today, the prototype may not be an adequate task trainer. Nonetheless, it has proven valuable as a mechanism for articulation work.

The main benefit of the current prototype has proven to be the representation of the 3D environment, where the realistic graphical style represents a familiar and recognizable setting from the user's everyday work. And even though the mechanics behind this layer of graphical realism has not yet proven to be adequate for representing the clinical practice the workers perform, it has still proven beneficial as it generated a discussion about the work that is actually being performed. The participants became engaged in a reflective activity, where they, based on what was wrong in the prototype, reflected on what is right in a thrombosis procedure. The prototype has therefore shed light on features of a thrombosis procedure, making room for a new type of reflection on the performance and a discussion around the articulation of the procedure. The project manager at ØHT explained how he thought there are more sides to this project than just the finalized application, and that the attention around such a process is just as valuable. Almost like a side effect, the process of developing the VS has generated constructive conversations and meetings with practitioners, developers and management, which has initiated a new focus on the thrombosis treatment. He explained how this type of focus makes the practitioners reflect on not just what they do, but also why they do it. So, by generating this discussion and shedding light on both the standard operating procedure and the situated practice, the current prototype has proven beneficial, in more ways than ØHT and Attensi may have first intended.

5.3 Implications for design

In this sub-chapter, I will address what the results and discussions regarding the research questions revealed when it comes to implications for design.

By having the thrombosis procedure virtualized, ØHT want to deploy a training tool that idealizes the treatment process, contributing to the standardization of the individual practices of the workers involved with thrombosis treatment. In many ways, the management want a coordination mechanism working as a training tool. A standardized routine is in theory an appropriate way to mediate a step by step procedure. However, as findings from the user tests and interviews with participants show, the prototype do not mediate the articulation of the collaborative work, only the individual tasks in themselves (Schmidt and Simonee, 1996). It do not take into consideration the highly situated nature of practice (Suchman, 1987; Brown and Duguid, 1991). Because of this, important information about the thrombosis performance is lost, which in many ways make the prototype resemble the rigid standard operating procedure.

The training tool is meant to compliment already established methods for mediating the procedure at the hospital. As the project manager at ØHT explained, the goal is not to replace previous training or the A3 tabletop simulation, rather to function as a contribution to the training methods already used by the practitioners. As an addition to the coordination mechanisms and training methods at the hospital, the VS should introduce something new. The management at the hospital could otherwise distribute the standard operating procedure to every worker. Up until now, this ‘something new’ has been to represent the operating procedure in a different form, where the team leader manages the collaboration of team members in a virtual space. The process has been virtualized, mediating what each practitioner should be doing throughout an idealized procedure. Where the operating procedure is a document-based instruction, this new mediation form visualizes the complex and tangled procedure, rendering the collaboration in the CT scan room visible for the practitioner.

5.3.1 Development

Designing and developing this complexity has been a challenge. According to the project manager at Attensi, they have never before developed something this intricate, and spent a lot of time during the project’s initiation phase trying to figure out how to proceed with the project. Further development involved obtaining information about the procedure from the management at ØHT, studying the standard operating procedure, making conversations with senior doctors, and observing the thrombosis treatment. Throughout the development of the prototype, the management at the department and representatives from Attensi have also performed workshops, discussing the procedure, all resulting in the current prototype.

For virtualizing and 'gamifying' a procedure this complex, it could however be beneficial to take another development approach. Attensi's current approach involves establishing requirements, and obtaining descriptions and feedback mainly from the management at ØHT. As this prototype do not resemble anything Attensi has ever created, it could be favourable to take a more action-based research method, where developer, researcher and user are working together in a collaborative and iterative process, all to uncover the most appropriate way to represent the treatment as a VS.

Taking a more practice-based approach could also have proven beneficial, shedding light on the nature of the work they are designing for, including how practitioners manage different contingencies and the situated nature of their work. This way, the prototype would not mainly resemble the canonical work procedure, but further correspond with the actual practice of performing the thrombosis treatment. Like Blomberg and Karasti (2013) explain, work activities, especially work that needs collaboration to be successfully performed, must be understood within a larger context (Blomberg and Karasti, 2013). These activities have to be seen as a chain of interlinked events. Without this understanding, analysing the work will lead to limited or even misleading results. Everyday clinical work is situated, and like Gerson and Star (1986) explain, it is impossible (both in theory and practice) to plan for every contingency (Gerson and Star, 1986). Because of this, formal descriptions, however well designed, are always underspecified (Koschmann et al., 2006; Suchman, 1987). Managing the interdependent nature of collaborative work requires the employees to improvise and resolve devotions and consistencies as they arise. Therefore, when designing support systems for collaborative workplaces, one should study the people and the nature of that work (Nardi, 1996).

However, taking a more practice-based approach would not have been without challenges, as the practitioners seem conflicted regarding what that practice actually is. The practitioners participating in the user tests, interviews and informal conversations, have different views of the thrombosis treatment. The project manager at Attensi explained that every practitioner they asked to describe the procedure gave different answers. Therefore, one of the main challenges with the development of the prototype was to accurately capture the essence of the process so as to develop a correct and realistic application. One participant of the user test further emphasized this; he was conflicted, explaining how he had helped Attensi by describing the work process and answering questions about the casuistry and the logic within the procedure. He found the prototype less logical than real life, further seeming to acknowledge that his descriptions may not have been accurate enough to be represented in the prototype. Standardizing and abstracting multifacet practices into a virtual task trainer, and then mediating this abstraction back to the practitioners, have therefore proven a complicated task.

During the interview, the project manager at Attensi said that the dispute about correct practices is a good reason for the development of this kind of task trainer, as it will help to get a more unified view of the thrombosis treatment. However, thrombosis treatment is a complex work procedure, and creating the application by 1) just virtualize the formal thrombosis protocol or 2) the descriptions from practitioners, have yielded an inadequate presentations of the standardized, formal procedure ØHT and Attensi want to create.

5.3.2 Design tensions

There is a tension between wanting to standardize clinical work and support seamless practice. This is what Bardram (1997) referred to as the *planning paradox*, writing that

> "On the one hand, due to the contingencies of the concrete work situation work has an ad hoc nature. Plans are not the generative mechanisms of work, but are merely used to reflect on work, before or after. On the other hand, we find that plans, as more or less formal representations, play a fundamental role in almost any organisation by giving order to work and thereby they effectively help getting the work done" (Bardram, 1997, p. 2).

The tension between canonical and non-canonical work is further addressed by multiple researchers (Brown and Duguid, 1991; Gross, 2013; Symon et al., 1996). Brown and Duguid (1991) explain that a canonical approach is abstracting and "downskilling" work, and although strict, directive procedures are a necessity for medical procedures, this downskilling "threatens the robust working, learning and innovating communities and practice of the workplace" (Brown and Duguid, 1991, p. 53). Where the practitioners involved with the thrombosis treatment have previous learned about the procedure through the community of practice, and in a highly situated environment, this downskilling is in theory making the workers less equipped to manage deviations.

However, when presented with greater contingencies (e.g. as with the wake-up stroke), the articulation of the collaborative work broke down. This could be a result of the high turnover of practitioners; without experience, workers are not able to collectively manage these situations. A task trainer would therefore be beneficial, however this task trainer should not limit but rather focus on strengthening workers collaborative and improvisational skills.

Attensi are finding themselves in the intersection between either designing for canonical work or non-canonical practice. Based on how they have collected information to create the prototype, they have started a process that may converge the formal procedure and the informal practice. However, they currently resides in the struggle between virtualizing the abstract procedure or contextual practice, asking how to best balance the application so that it support the formal plan *and* the situated action. According to Gross (2013), finding the balance between flexibility and constrain is one of the core struggles when designing and developing coordination mechanisms, further stating that

> "these kind of organizations [with strict, hierarchical structure] raises pressing requirements to find the right (and we would say ecological, sustainable) balance between flexibility and control [..]"(Gross, 2013, p. 45).

Referring to a study investigating workflow systems in a hospital performed by Symon et al. (1996), Bardram (1997) explained how these design tensions can be overcome by *situated planning*, which attempts to deal with how workflow systems often exists in the intersection between canonical and non-canonical work (Bardram, 1997; Symon et al., 1996). Even though they referred to digital planning systems which purpose were to support coordination of patient treatment in a medical ward, and not a VS of one specific emergency treatment, the main purpose was to design a computer system supporting both the plan and the practice. This was solved by making the practitioners active contributors to the system, where they were able to contribute and make modifications to the system so that it was continuously improved and updated with possible contingencies and courses of action that are usually left out by the organizational management. This is similar to what Gross (2013) referred to as the "struggle for flexibility", i.e. designing coordination mechanisms that support malleability and changes from the user-side (Gross, 2013). This process however, may be an "iterative and perhaps open-ended co-evolution of the understanding of work practices" (ibid, p. 43). After all, practice is constantly evolving, and are continuously being shaped by individual workers and unforeseen events.

This situated planner may be a solution when developing plans and schedules for the hospital. However, whether this is an adequate solution for a task trainer which function is to artificially simulate a procedure, is another matter. User modifications may not be an option, given that the system behind the VS is very complex. The project manager at ØHT expressed that the hospital do not want to work with software development, as it requires a lot of resources and experience. However, he explained that there have been talk about using Attensi's virtualization editor and their resource library, functioning like an advances PowerPoint editor; with drag-and-drop functionality, all the code is represented as pre-built "blocks". The head of department explained how this could enable easy implementation of more scenarios. However, the project manager further explained that there is a large gap in the hospital sector regarding innovation, and that they will then face challenges when it comes to the ownership of the product, service and support.

Because of this, designing for situated planning as described by Symon et al. (1996), Bardram (1997) and Gross (2013), may not necessarily be an efficient approach. The tension between flexibility and control is something that needs further attention from researcher concerned with CSCW.

5.3.3 Realism and abstraction

This section will present considerations for design, a topic that may be addressed more appropriately in another research field (e.g. HCI). However, as findings from this study has shed light on how the VS represents awareness information, I find it an important subject of both design and CSCW.

One should also consider *how* the thrombosis procedure is represented. What "type" of representation is best suited for training practitioners? Is having a high level of graphical similarity a premise for learning the procedure? Perhaps a realistic VS is not the most applicable method, as there are so many factors that cannot be represented well. When thrombosis treatment is displayed on a static screen, a lot of valuable information, e.g. awareness information, is lost. Designing for awareness support, or what Schmidt (1994) described as modes and means of interaction, are crucial characteristics of cooperative work as they help articulate the situated work activities between collaborative workers.

It should be noted that the assumption of the prototype's level of realism being inadequate for mediating a collaborative work procedure is derived from evaluating a prototype. Given more resources, Attensi may be able to implement features that makes it easier for the user to interpret and interact with virtual characters. However, as the prototype is now, it could be an idea to design the task trainer similar to that of the first part of the game, as solving objectives like arranging tasks and creating check-lists were easier and demanded less of the user's attention and perception of video game mechanics. These objectives can be seen as in-game coordination mechanisms, making the VS function as a coordination mechanism in two different levels; first, as a coordination mechanism equal to that of the standard operating procedure. Secondly, as features inside the VS, like the check-list and the arranging of tasks, acting like virtual representation of coordination mechanism. Participants found the objectives regarding the latter easier than instructing virtual co-workers in the CT scan room. It was during the part in the CT scan room that they started getting negative points and expressed frustration. One participant commented that the simulation was too fast paced, and that observing, perceiving and reacting (e.g. correct the virtual characters' behaviour) were almost impossible (#2). He further explained that if he "in a real situation had observed him [the team member] do something seriously wrong [he could direct the situation], but I do not know what I got negative points for in the game. It just happened". Therefore, just like the standardized protocol is an abstraction of practice, abstracting the task trainer may be beneficial.

In the studies performed by Graafland et al. (2013; 2014; 2015; 2017), they investigated whether a serious game could improve surgeons' response to equipment failure (Graafland and Schijven, 2013; Graafland et al., 2014, 2015, 2017). In an endeavour to provide surgeons with an efficient training application, they developed a block-based mini-game (see figure 1.3).The purpose was to investigate whether the abstracted, serious game had a potential to improve situation awareness in minimal invasive surgeries (MIS), i.e. surgery that uses techniques to operate with minimal damage to the patient. These mini-games were not developed to resemble the MIS environment, rather they were simplified and abstracted from the real world.

The user test uncovered that participant found it difficult to perceive and successfully interact with the collaborative part in the prototype. Therefore, just like the serious game developed by Graafland et al. (2013; 2014; 2015; 2017) is abstracted from the MIS procedure, perhaps the entire course within the VS should be made similar to that of the first part of the simulation, reducing the user's interactions, making the simulation more manageable. Abstracting the simulation to this level, focusing on the order of the different activities, rather than on simulating realistic interactions, could prove more beneficial and closer to the idea of creating a *task trainer* than a realistic simulation.

That being said, using a more realistic approach have proven useful as the participants were presented with a familiar environment. Even though collaboration with the virtual characters were challenging, several participants expressed that visualising co-workers activities and positions were valuable. By making the simulation seem even more familiar to the practitioners, improving the logic and the mechanics of the simulation, could further prove the VS valuable as a coordination mechanism. This however, will require that the VS supports characteristics that is fundamental to the collaborative setting of a thrombosis treatment, making it easier for the user to perceive and interact with events. During the user test, it becomes evident that supporting these collaborative attributes are important to the user.

The simulation should therefore include features from theories of awareness, with clearer animations and more logical interactions e.g. for correcting the virtual characters. During this study, awareness has been revealed as an important attribute, especially for work where practitioners engage in interdependent, co-present collaboration. The collaborative nature of the thrombosis procedure, where workers positively relies on each other's timeliness, requires the practitioners to be aware not only of their own work, but also of the surrounding environment and operatives in this environment. Practitioners are constantly monitoring both their surroundings and fellow workers in anticipation of performing their own tasks. Here, practitioners give various awareness cues, like verbal signals in the form of dialogue or loud statements. For example, nurses preparing the patient in a procedure should give a clear signal when they are finished sampling blood, so as to alert and inform waiting co-workers that they can proceed with their respective work. Awareness cues helps practitioners to make an informed decision of how they can contribute to reach the group's collective goal.

Awareness information is not adequately presented with the level of realism the application wants to simulate. After using the VS, several participant expressed that it was hard to understand what the virtual characters were doing, making it difficult to complete the objectives in the VS. Perceiving, interpreting and mediating awareness information is easier to perform in real life than in a VS. The screen's interface is limiting the user's interaction, not supporting the immersion that seems to be needed to fully be aware of one's surroundings. The prototype was not able to represent the dynamics of a collaborative work procedure. As much information is lost when trying to mediate a real thrombosis treatment to a display screen, the level of realism is weakening, rather that strengthening, the user's impression of the collaborative setting.

One can also question how events are presented to the user in a realistic simulation. In the CT scan room, the user monitors the setting through a camera position giving a bird-eye-view of the room. This may not be the most appropriate way to represent the monitoring of co-workers, as it distances the user from the action, making at hard to capture the details of the virtual procedure. This representation form may be more suitable for classroom teaching, showing the different professions where to stand and how to act throughout a procedure. The project manager at ØHT expressed that this type of teaching proved valuable in the previous virtualization project at the hospital. As a training tool for individual practitioners, it could prove more beneficial using a first or third person point-of-view, also designing for a higher degree of freedom when it comes to movement, further immersing the player into the thrombosis treatment. This bring the user closer to the action, and are able to perceive characteristics like facial expressions of the virtual co-workers and patient. However, this could prove challenging as the main goal of the VS is for the user to rapidly solve different objectives. Being free to explore the virtual space may distract the player, decreasing the value of the VS as a task trainer. Also, this type of freedom demands a higher level of understanding of video game mechanics.

Nonetheless, developing a hyper-realistic simulation supporting seamless interactions and awareness attributes will demand considerably more resources. The cost is high, and there is a moderate risk of failing to create a simulation that is adequate for supporting this type of collaborative work.

A third option is to take what works best from both categories, combining realism and abstraction. This can be solved using a mixture of realistic, cinematic presentations of the thrombosis treatment, and abstracted, but interactive, objectives like with the in-game coordination mechanisms where the user creates check-lists and arranges tasks.

5.4 Recommendations for future development of the prototype

The research findings from this study are based on the prototype of a VS. This prototype are yet to be finalized and to reach its full potential. There are therefore aspects regarding a VS this thesis has not been able to capture and evaluate. Among these are the end result of the VS, and what kind of impact it will have on the performance of the thrombosis treatment.

It may be that the VS is going to contribute to a convergence between canonical and non-canonical work at the department. That by shedding light on important features of performing a situated procedure, the VS helps to bridging the gap between formal descriptions and practice.

What ever the final outcome of deploying the VS as a training tool for practitioners of the thrombosis treatment is, the current prototype needs further development to become an valuable task trainer. When continuing with the creation of a realistic simulation, ØHT and Attensi ought to recognise the importance of designing for effortless awareness support; providing sufficient awareness cues all the while keeping the effort of achieve and maintain it low. The VS should contain randomized scenarios with different levels of contingencies so as to make the practitioners better equipped to deal with the situated nature of the procedure. The VS should also be designed with greater flexibility. Like one informant explained after using the prototype, "there is not always something that is completely wrong or completely right" regarding the practice of performing a thrombosis treatment (# 6).

The management at ØHT should also consider how this new task trainer is to be successfully implemented into the workplace, so as to not seem obtrusive to the practitioners.

5.4.1 Designing awareness support

The VS should more sufficiently support the presentation of awareness information. According to Gross (2013), digital systems should 1) share work-oriented information about co-workers, 2) general information about who is currently available in the system, 3) detailed descriptions of each worker and 4) yield feedback on any changes done by the co-workers (Gross, 2013). In the prototype, the user can study what co-workers are doing and inspect co-worker activities in the virtual space. Clicking on a character yields the status of current activity and information about character's availability. The users can also use their knowledge about the routines of the real co-workers to examine whether they are in the right position to perform their respective work. The prototype should further provide the user with relevant awareness information. According to interviews and observations made during the user test, participants found it hard to achieve and maintain awareness of events and current objectives. The users could not analyse the virtual characters' activities through suitable animations or facial expressions, resulting in that several participants expressed frustration as they could not interpret what the virtual character were doing. As one informant explained, "[..] I did not understand what they [the virtual workers] where doing. They stood there and fiddled, and you didn't understand what they where actually doing before it was too late [..]" (# 5). Even though it is not necessary to visualise the exact activity of each worker e.g. using realistic gestures and facial expressions, the VS should provide users with sufficient context cues, like the role, location, status and activity of each character.

When designing for realistic simulations, the presentation of awareness cues are important for the user's ability to perceive events. However, they should be designed so as not to demand a lot of effort from the user; it needs to be *effortless*. Further, giving the right amount of cues are important. The presentations needs to be balanced, or else it may actually undermine the user's ability to perceive the current event. As seen during the user tests, a combination of 1) too much movement on the screen, including drop-down text boxes and character animations, and 2) uncertainties about team members tasks, were weakening rather that strengthening the user's ability to make sense of the situation.

This may be of especial importance for users with little or no experience with this type of technology.

Furthermore, a combination of the fast-paced nature of the simulated thrombosis treatment and the rapid changing of screen elements seemed to steal the participants attention. Gross (2013) explain that the downside of systems that is to support the coordination of practitioners in distributed workplaces, is that it requires additional effort of the users, as they are unable to display awareness cues or monitor each others activities (Gross, 2013). Although the VS do not feature real-time collaboration between workers positioned in different locations, I find Gross' 2013 theory about effortless coordination relevant, as the user is relying on technology mediated awareness cues while resolving asynchronous collaboration with virtual agents.

Several participants expressed that it was hard to collaborate with the virtual characters. In real thrombosis procedure, team members engage in dynamic conversations. In the prototype, the user is limited to an instructing interaction type, e.g. engaging in a one way conversation, giving commands to the system (Rogers et al., 2011). Instead of being able to have a dynamic and mutual dialogue with co-workers, the user is presented with a simulated abstraction of human interactions. However, the participants expressed that the prototype shed light on co-workers activities, contributing to reflections on and visualizing of in situ articulation work. This way, the prototype do indirectly support mutual awareness information, as it in addition to his or her own responsibilities in the CT scan room made the user reflect on the distributed work activities of a thrombosis treatment. This reflection may be recalled later, when the user are performing the treatment. However, mutual awareness is not presented as a dynamic construct, which is an important factor when exchanging awareness information (Gross, 2013).

The requirements for awareness support is best understood when being inspected in the work environment the digital system is to be used in (ibid). However, Gross (2013) explains that the modelling effort of these systems are quite high; tailoring unique systems demands considerable resources. Also, these systems are less malleable and less adaptable to changes. Should the work procedure of the thrombosis treatment change, which it frequently has, adapting the VS accordingly will require resources.

5.4.2 Designing for situated action

In sub-chapter 5.3, I addressed the tension between supporting canonical and non-canonical work when designing support systems. Relying on the standard operating procedure when designing these systems will give a poor expression of the work that actually needs doing during a procedure. However, mainly using the descriptions given by the practitioners will yield an imprecise image of the procedure as their impression of the thrombosis treatment is derived from unique and individual experiences. But whether the developers decides to virtualize the standard operating procedure or take a more practice-based approach, they need to consider how to balance the canonical operating procedure and the non-canonical practice.

Findings from this study implies that the application should not be as rigid as the standard operating procedure. Bardram (1997) argues that a plan should not be presented as a rigid template, but rather as a resource supporting actual work (Bardram, 1997). As a real clinical performance is highly situated, it cannot always be supported by a formal plan. The VS should therefore contain the critical steps of the operating procedure, but also present the user with case alternations and contingencies. This can be achieved by designing and using randomized scenarios, where the user is introduced to new patients and different types of deviations. Both management at ØHT and Attensi have already expressed that this is something they want implemented in the finalized application. The head of department states that unknown and randomized scenarios has to be implemented in the VS as the variations of the occurring cases are almost infinite. He explained that "[...] the procedure is static. You know what to do. But the challenge is that there are 15 resident doctors and 80 acute nurses, increasing the variability almost indefinitely". In addition, each incoming patient is unique. Designing for deviations is also going to make the VS less tedious to play. This way, the VS can further support actual practice.

The developers should also consider designing for greater flexibility within each scenario. One participant explained how the creating of the check-list (see figure 1.11) should contain more alternatives to chose from, "as there are more objectives to do [in a procedure] than what comes up [as alternatives]" (# 7). Including more alternatives in the entire VS, the users can after their own ability reach the best possible ending for the current virtual patient. At the end, the choices the user made during the playthrough could be presented in the end of the VS, giving feedback on how the user could optimize their own performance.

By taking it a step further, the developers can design for different consequences of the choices made by the user, adapting the story to the user's choices. Through branching scenario design, the user can then see what consequences his or her action would have in a real treatment, and learn what consequence each choice have on the treatment outcome.

Implementing randomized scenarios and greater flexibility may further support learning as seen from Schön's 2017 theory of reflection in and on action. It may also further contribute to supporting non-canonical work, making the application seem less intrusive to the community of practice. However, it will demand a lot of development resources, corresponding to Gross' 2013 notion of increased modelling effort.

5.4.3 Implementation of a VS at the hospital

ØHT should consider how to distribute the VS as training tool for the practitioner of thrombosis treatment. The VS may not work well as a stand-alone training tool, and it may be beneficial to implement it as a part of a larger training program, with a clear training plan. Like the project manager explained, it may be valuable to have it compliment the simulation training in the CT scan room, or as a debriefing tool used after a thrombosis treatment. One participant suggested that it could work similar to that of the CPR training, where the practitioners first participate in an theoretical sessions before engaging in an interactive CPR course.

Performing debriefings after thrombosis treatments are depended on whether a senior doctor has time to observe the treatment and whether the senior doctor and the practitioners have time to stay for the debriefing. Using the VS after a thrombosis treatment may therefore be useful, as it can compensate for a physical debriefing.

The VS may also work as a briefing method before thrombosis treatment. The head of department explained that when performing a briefing before patients arrives at the emergency ward have resulted in less deviant behaviour from the practitioners. A VS may present a more in-depth orientation of the thrombosis treatment than a verbal briefing. However, using the VS as a briefing tool is more time-consuming than a verbal briefing.

If the VS are to function as a stand-alone training method, and not as a compliment to simulation training or performing thrombosis treatment, the head of department explained that it is desirable to begin with a briefing of the standard operating procedure before practitioner use the VS. At the end, the users should take part in a debriefing, discussing how they used the simulation when compared to the operating procedure. This way, the VS can be used as a part of training workshops. It may also be beneficial for the depart of neurology to arrange classroom training sessions, where a senior doctor goes through the simulation on a display screen, opening up for a discussion of the treatment where the entire team can reflect on their performance and how this influences the ongoing treatment.

Further, ØHT should be aware of possible tensions when deploying the VS into the workplace. In the paper Organizational Issues in Groupware Implementation, Orlikowski (1992) sheds light on complications that can occur when new technological systems are implemented into the workplace (Orlikowski, 1992). If the system being deployed is too unfamiliar, it will challenge the employees' *mental models* and *technological frames*. Mental models are our internal, cognitive references which help us perceive, reason and develop new knowledge of digital systems - how to interact with systems and how, in various degrees, that system works (Orlikowski, 1992; Rogers et al., 2011). Encounters with unknown systems are filtered through these internal models. Orlikowski (1992) explains that when confronted with unfamiliar technology, people will try to understand that new system using their existing technological frames. If the new system is too different from what the users are accustomed to, their existing frames are not appropriate and will need to be modified. This modification process is influenced by 1) "the kind and amount of product information communicated to them", and 2) "the nature and form of training they received on the product" Orlikowski (1992, p. 6).

During usability tests, participant were asked whether they had used similar virtual simulations or was experienced with playing video games. Participants who already had some experience with video games used the prototype without major difficulties (not including bugs and breakdowns). However, one participant had not before encountered this type of application, and expressed frustration and uncertainty when using the VS.

When analysing the video recordings from user test, participants seems to have an increased understanding of how to solve the different objectives when using the prototype the second time. Even though one could argue that this is due to the participants ability to recall events from their first playthrough, it may also be an indication of extended technological frames. Without further testing, this cannot be confirmed in this project, but it should be considered when implementing the VS at the hospital; first time users may express reluctance, finding the simulation difficult as they have never before encountered this type of technology. However, repetitive usage could extend and update the users' mental models, making the VS easier to use over time.

Given the broad population at the hospital the VS may seem unfamiliar to many practitioners. When introducing the VS to the practitioner at the department, ØHT should consider creating a formal implementation plan or information dissemination strategy is necessary (Orlikowski, 1992). Workers need to be given appropriate information about what the new system is and why the organisation is implementing it into the workplace. Without an explicit explanation, the individual workers are going to make their own assumption about the technology, often leading to an "[..] poor or inappropriate understanding of the unique and different features of a new technology[..]" (ibid, p. 3). The result may be that the workers do not properly integrate the system into their workplace, or may resist using it altogether. Orlikowski (1992) suggest deploying the VS as a prototype to the

> "[..] representative group of the organization–on a pilot basis–and then deploy it to the rest of the organization once the technology's capabilities and implications are understood" (ibid, p. 9)

This will help ease the practitioners' transition between training methods, as the change in cognitive structures partly takes place before fully distributing the system.

There are no similar hospital that has developed and implemented a VS for this purpose. Therefore, ØHT cannot compare the results with similar projects. When it comes to evaluating the effect the VS will have on the treatment and practitioners responsible for it, are only visible after deploying it at the department. If the time of thrombosis treatments decrease, the VS may have had a positive influence on the practitioners' performance. The project manager explained that measuring the effect of the VS may be a challenge, especially what kind of effect it has. Further, he explained that the downside to using this type of technology for other purposes that entertainment is that it has a high hype-factor; people express that they think it's cool because it looks cool. It is first after the VS is integrated and accepted as a training tool by the practitioners that ØHT will obtain more correct feedback.

Research findings from this study has revealed how participants reflected on co-workers responsibilities during a thrombosis treatment. As a tool that prepare and extend the practitioners understanding about the treatment may also extend their overall knowledge about the field, thus making them better equipped to manage contingencies and deviations that can occur during treatments. However, when it comes to the learning outcome of the system, one need to question the cause of a possible reduced treatment time. Is it exclusively because of the system's ability to mediate the thrombosis treatment, or is it because the project has rendered the thrombosis procedure more visible to the practitioners?

Chapter 6

Conclusion

Compared to national numbers, the survival rate of incoming patients diagnosed with thrombosis at ØHT is significantly low. As a result, the management at the department of neurology have taken measures to optimize the standardized procedure, increasing the efficiency of each procedural step. Due to the high turnover of practitioners at the department, most of the workers responsible for the thrombosis treatment lack the experience needed to further reduce the treatment time for incoming patients. Giving the practitioners a sufficient training tool is therefore important, as it may generate knowledge and a further understanding of the procedure. ØHT is currently having a VS developed, hoping the application will function as a virtual task trainer for the practitioners involved with thrombosis treatment.

When inquiring about how the prototype of a VS can train practitioners on performing collaborative clinical practice, I have used a theoretical framework containing concepts from CSCW and practice theories, including communities of practice, articulation work and theories of awareness. Using methods like field observations, interviews and user tests, this thesis has shed light on whether the prototype has potential as a training application, virtually mediating the collaborative treatment to the practitioners.

During this study, the prototype has triggered a reflection regarding the work performed during thrombosis treatment, suggesting that a finalized VS has value as a training tool that may extend the practitioners' understanding of the treatment. Today, workers learn and train on their respective tasks mainly during the performance of thrombosis treatment. By participating in the community of practice - the group of collaborative individuals responsible for this treatment - at the emergency ward, workers learn the required skills to perform the procedure. The prototype shed light on the work responsibilities of the different professions involved with the procedure, and supplied the users with a further understanding of the collaborative performance of the thrombosis treatment. The learning outcome from the use of the VS will however first be visible after it is deployed as a training tool for the practitioners involved with the treatment.

The collaborative nature of the treatment requires articulation work. The management at the department of neurology have during an ongoing articulation work process developed several coordination mechanisms - artifacts mediating canonical work descriptions for managing and optimizing the thrombosis treatment. As one such canonical description, the standard operating procedure gives a general and abstracted description of the individual work activities performed during thrombosis treatment. It do not however mediate the situated performance of the collaborative work. The situated nature of a thrombosis treatment calls for in situ articulation work, where practitioners must deviate from the formal descriptions to manage various contingencies. Coordination mechanisms used for training practitioners in collaborative workplaces should therefore 1) mediate the canonical descriptions and 2) support the non-canonical practice. This however, present various design tensions, often requiring developers to make compromises.

Mediating the collaborative performance of a thrombosis treatment using the prototype of a VS has shed light on various design challenges. In these performances, workers are required to use complex social skills, presenting and perceiving awareness information about co-workers and their surroundings. When artificially simulating this collaboration using a computer screen, important information about the situated performance of a real emergency procedure is lost. The screen's interface is limiting the users' interpretation of, and their ability to make an informed decision about, the simulated collaborative work. Designing a VS which present the users with sufficient awareness information may further increase the application's worth as a training tool.

As a training tool simulating the collaborative thrombosis treatment, the VS can compliment current training methods at the department. Without being time-, team- or location-dependent, the VS can be used to gain further insights about the treatment. If successfully implemented at the department, the training tool has the potential to reduce the turnover rate of practitioners, as the VS may present clearer guidelines for performing the procedure. This may further improve the survival rate of incoming patients diagnosed with thrombosis at ØHT, as an increased understanding of the procedure may decrease the average treatment time.

6.1 Future work

Continuing to follow the collaboration between ØHT and Attensi, evaluating further development and implementation of the VS at the hospital may yield valuable information.

It may be interesting to investigate the learning outcome and learning opportunities this type of technology can yield when used to train practitioners of collaborative emergency treatments. Several researchers have already addressed how virtual technologies can be used for collaborative learning, e.g. in the research field of CSCL where serious games have proven valuable tools (Zea et al., 2009; Echeverría et al., 2016). If using the VS for training practitioners at ØHT proves valuable, inquiring about the correlation between 1) the increased understanding of the procedure and 2) the decreased treatment time may be a beneficial asset to further using virtualization technologies in collaborative workplaces.

This study has shed light on the importance of the mediation of awareness information in realistic VSs. Further research regarding the representation of awareness cues could be beneficial. This may be more appropriately addressed in another research field (e.g. HCI). However, should the VS prove useful for training practitioners engaged in collaborative work, it is important to find the balance between mediating awareness cues and overloading the user with information. As addressed by Gross (2013), the information needs to be mediated without causing considerable effort from the user, and is something researchers of collaborative technologies should further inspect.

When developing a VS for collaborative work, the tensions between designing for canonical and non-canonical work should also be addressed. Given the situated nature of the thrombosis treatment, developers should consider how to present the standard procedure all the while supporting clinical practice. This is already addressed by researchers like Gross (2013) and Symon et al. (1996), where the challenge of *designing for flexibility* can be solved using *situated planning*. Designing for situated planning may however be more achievable when developing e.g. digital schedules and planning tools, as allowing users access to modify and add content in a VS may require considerable more effort from the developers designing the system and from the practitioners which are to add content to the VS. If this type of technology proves valuable for supporting collaborative work, the developers of the VS, and researcher and designers concerned with the research field CSCW and CSCL, should consider possible solutions for how a VS sufficiently can support both the plan and the practice of the collaborative work.

As briefly discussed in sub-chapter 5.2, it would also be interesting to see whether further including the practitioners in the development process (referred to as participatory methods or participatory design (Muller and Kuhn, 1993)) using workshops and iterative development may shed further light on the requirements for the design of a sufficient training tool for collaborative practitioners at the hospital. Taking a more action-based research approach may result in a VS which more sufficiently works as a training tool for the practitioners of the thrombosis treatment at ØHT.

Bibliography

Bannon, L. J. and Schmidt, K. (1989). Cscw-four characters in search of a context. *DAIMI Report Series*, 18(289).

Bardram, J. E. (1997). Plans as situated action: an activity theory approach to workflow systems. In *Proceedings of the Fifth European Conference on Computer Supported Cooperative Work*, pages 17–32. Springer.

Bardram, J. E. and Hansen, T. R. (2010). Context-based workplace awareness. *Computer Supported Cooperative Work (CSCW)*, 19(2):105–138.

Barley, S. R. and Kunda, G. (2001). Bringing work back in. *Organization science*, 12(1):76–95.

Benford, S., Greenhalgh, C., Rodden, T., and Pycock, J. (2001). Collaborative virtual environments. *Communications of the ACM*, 44(7):79–85.

Berlage, T. and Sohlenkamp, M. (1999). Visualizing common artefacts to support awareness in computer-mediated cooperation. *Computer Supported Cooperative Work (CSCW)*, 8(3):207–238.

Blomberg, J. and Karasti, H. (2013). Reflections on 25 years of ethnography in cscw. *Computer Supported Cooperative Work (CSCW)*, 22(4-6):373–423.

Borning, A. and Travers, M. (1991). Two approaches to casual interaction over computer and video networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 13–19. ACM.

Braithwaite, J., Wears, R. L., and Hollnagel, E. (2016). *Resilient Health Care, Volume 3: Reconciling Work-as-Imagined and Work-as-Done*. CRC Press.

Brown, J. S. and Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. *Organization science*, 2(1):40–57.

Cabitza, F. and Simone, C. (2013). Computational coordination mechanisms: A tale of a struggle for flexibility. *Computer Supported Cooperative Work (CSCW)*, 22(4-6):475–529.

Correia, A., Fonseca, B., Paredes, H., Martins, P., and Morgado, L. (2016). Computer-simulated 3d virtual environments in collaborative learning and training: meta-review, refinement, and roadmap. In *Handbook on 3D3C Platforms*, pages 403–440. Springer.

Creswell, J. (2012). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications.

Creutzfeldt, J., Hedman, L., Medin, C., Heinrichs, W. L., and Felländer-Tsai, L. (2010). Exploring virtual worlds for scenario-based repeated team training of cardiopulmonary resuscitation in medical students. *Journal of medical Internet research*, 12(3).

Dawley, L. and Dede, C. (2014). Situated learning in virtual worlds and immersive simulations. In *Handbook of research on educational communications and technology*, pages 723–734. Springer.

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., and Dixon, D. (2011). Gamification. using game-design elements in non-gaming contexts. In *CHI'11 extended abstracts on human factors in computing systems*, pages 2425–2428. ACM.

Dourish, P. and Bellotti, V. (1992). Awareness and coordination in shared workspaces. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work*, pages 107–114. ACM.

Dourish, P. and Bly, S. (1992). Portholes: Supporting awareness in a distributed work group. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 541–547. ACM.

Echeverría, A., Gil, F., and Nussbaum, M. (2016). Classroom augmented reality games: A model for the creation of immersive collaborative games in the classroom.

Gaver, W., Moran, T., MacLean, A., Lövstrand, L., Dourish, P., Carter, K., and Buxton, W. (1992). Realizing a video environment: Europarc's rave system. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, pages 27–35. ACM.

Gerson, E. M. and Star, S. L. (1986). Analyzing due process in the workplace. *ACM Transactions on Information Systems (TOIS)*, 4(3):257–270.

Ghanbarzadeh, R., Ghapanchi, A. H., Blumenstein, M., and Talaei-Khoei, A. (2014). A decade of research on the use of three-dimensional virtual worlds in health care: a systematic literature review. *Journal of medical Internet research*, 16(2).

Gherardi, S. and Nicolini, D. (2002). Learning in a constellation of interconnected practices: canon or dissonance? *Journal of Management Studies*, 39(4):419–436.

Goody, J. (1987). *The Interface between the Written and the Oral*. Cambridge University Press.

Graafland, M., Bemelman, W. A., and Schijven, M. P. (2014). Prospective cohort study on surgeons' response to equipment failure in the laparoscopic environment. *Surgical endoscopy*, 28(9):2695–2701.

Graafland, M., Bemelman, W. A., and Schijven, M. P. (2017). Game-based training improves the surgeon's situational awareness in the operation room: a randomized controlled trial. *Surgical Endoscopy*, pages 1–9.

Graafland, M. and Schijven, M. P. (2013). A serious game to improve situation awareness in laparoscopic surgery. In *Games for Health*, pages 173–182. Springer.

Graafland, M., Schraagen, J. M. C., Boermeester, M. A., Bemelman, W. A., and Schijven, M. P. (2015). Training situational awareness to reduce surgical errors in the operating room. *British Journal of Surgery*, 102(1):16–23.

Gross, T. (2013). Supporting effortless coordination: 25 years of awareness research. *Computer Supported Cooperative Work (CSCW)*, 22(4-6):425–474.

Gross, T., Stary, C., and Totter, A. (2005). User-centered awareness in computer-supported cooperative work-systems: Structured embedding of findings from social sciences. *International Journal of Human-Computer Interaction*, 18(3):323–360.

Gutwin, C. and Greenberg, S. (2002). A descriptive framework of workspace awareness for real-time groupware. *Computer Supported Cooperative Work (CSCW)*, 11(3-4):411–446.

Hansen, M. M. (2008). Versatile, immersive, creative and dynamic virtual 3-d healthcare learning environments: a review of the literature. *Journal of medical Internet research*, 10(3).

Heath, C., Svensson, M. S., Hindmarsh, J., Luff, P., and Vom Lehn, D. (2002). Configuring awareness. *Computer Supported Cooperative Work (CSCW)*, 11(3-4):317–347.

Howard, V. M., Englert, N., Kameg, K., and Perozzi, K. (2011). Integration of simulation across the undergraduate curriculum: Student and faculty perspectives. *Clinical Simulation in Nursing*, 7(1):e1–e10.

Iedema, R. (2011). Creating safety by strengthening clinicians' capacity for reflexivity. *BMJ quality & safety*, 20(Suppl 1):i83–i86.

Innovation in Learning, Inc (n.d.). Virtual sim center. [Online; accessed May 05, 2018].

Koschmann, T., LeBaron, C., Goodwin, C., and Feltovich, P. (2006). The mystery of the missing referent: Objects, procedures, and the problem of the instruction follower. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work*, pages 373–382. ACM.

Kvale, S., Brinkmann, S., Rygge, J., and Anderssen, T. (2015). Det kvalitative forskningsintervju (3. utg.) oslo: Gyldendal akademisk.

Lave, J. and Wenger, E. (1998). Communities of practice. *Retrieved June*, 9:2008.

Muller, M. J., Kuchinskaya, O., Minassian, S. O., Tang, J. C., Danis, C., Zhao, C., Harrison, B., and Moran, T. P. (2005). Shared landmarks in complex coordination environments. In *CHI'05 Extended Abstracts on Human Factors in Computing Systems*, pages 1681–1684. ACM.

Muller, M. J. and Kuhn, S. (1993). Participatory design. *Communications of the ACM*, 36(6):24–28.

Muñoz, M. A., Rodríguez, M., Favela, J., Martinez-Garcia, A. I., and González, V. M. (2003). Context-aware mobile communication in hospitals. *Computer*, 36(9):38–46.

Nardi, B. A. (1996). Studying context: A comparison of activity theory, situated action models, and distributed cognition. *Context and consciousness: Activity theory and human-computer interaction*, 69102.

Nestel, D., Jolly, B., Kelly, M., and Watson, M. (2017). *Healthcare Simulation Education: Evidence, Theory and Practice*. John Wiley & Sons.

Nicolini, D. (2012). *Practice theory, work, and organization: An introduction*. Oxford university press.

Office of the Surgeon General (US and others) (2008). The surgeon general's call to action to prevent deep vein thrombosis and pulmonary embolism.

Orlikowski, W. J. (1992). Learning from notes: Organizational issues in groupware implementation. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work*, pages 362–369. ACM.

Oxenford Dictionaries (2017). Definition of contingency.

Palaganas, J. C., Maxworthy, J. C., Epps, C. A., and Mancini, M. E. (2014). *Defining excellence in simulation programs*. Lippincott Williams & Wilkins.

Prasolova-Førland, E. and Divitini, M. (2003). Collaborative virtual environments for supporting learning communities: an experience of use. In *Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work*, pages 58–67. ACM.

Qin, J., Chui, Y.-P., Pang, W.-M., Choi, K.-S., and Heng, P.-A. (2010). Learning blood management in orthopedic surgery through gameplay. *IEEE computer graphics and applications*, 30(2):45–57.

Rashid, M., Caine, V., and Goez, H. (2015). The encounters and challenges of ethnography as a methodology in health research. *International Journal of Qualitative Methods*, 14(5):1609406915621421.

Ricciardi, F. and Paolis, L. T. D. (2014). A comprehensive review of serious games in health professions. *International Journal of Computer Games Technology*, 2014:9.

Rittenbruch, M. and McEwan, G. (2009). An historical reflection of awareness in collaboration. In *Awareness Systems*, pages 3–48. Springer.

Ritterfeld, U., Cody, M., and Vorderer, P. (2009). *Serious games: Mechanisms and effects*. Routledge.

Robertson, T. (2002). The public availability of actions and artefacts. *Computer Supported Cooperative Work (CSCW)*, 11(3-4):299–316.

Rogers, Y., Sharp, H., and Preece, J. (2011). *Interaction design: beyond human-computer interaction*. John Wiley & Sons.

Schmidt, K. (1994). Cooperative work and its articulation: requirements for computer support. *Le travail humain*, pages 345–366.

Schmidt, K. (2002). The problem with 'awareness': Introductory remarks on 'awareness in cscw'. *Comput. Supported Coop. Work*, 11(3):285–298.

Schmidt, K. (2011). *Cooperative Work and Coordinative Practices: Contributions to the Conceptual Foundations of Computer-Supported Cooperative Work (CSCW)*. Springer Publishing Company, Incorporated, 1st edition.

Schmidt, K. and Bannon, L. (1992). Taking cscw seriously. *Computer Supported Cooperative Work (CSCW)*, 1(1):7–40.

Schmidt, K. and Bannon, L. (2013). Constructing cscw: The first quarter century. *Computer supported cooperative work (CSCW)*, 22(4-6):345–372.

Schmidt, K. and Simonee, C. (1996). Coordination mechanisms: Towards a conceptual foundation of cscw sys-tems design. *Computer Supported Cooperative Work (CSCW)*, 5(2-3):155–200.

Schön, D. A. (2017). *The reflective practitioner: How professionals think in action*. Routledge.

Silverman, D. (2001). *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction*. SAGE Publications.

Simonson, M. (2017). *Distance Learning-Volume 14 Issue 1 2017*. IAP.

Star, S. L. and Strauss, A. (1999). Layers of silence, arenas of voice: The ecology of visible and invisible work. *Computer supported cooperative work (CSCW)*, 8(1):9–30.

Stokowski, L. (2013). A digital revolution: Games, simulations, and virtual worlds in nursing education. *Medscape. WebMD, LLC.*

Strauss, A. (1988). The articulation of project work: An organizational process. *The Sociological Quarterly*, 29(2):163–178.

Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge university press.

Symon, G., Long, K., and Ellis, J. (1996). The coordination of work activities: cooperation and conflict in a hospital context. *Computer Supported Cooperative Work (CSCW)*, 5(1):1–31.

Zea, N. P., Sanchez, J. L. G., and Gutierrez, F. L. (2009). Collaborative learning by means of video games: An entertainment system in the learning processes. In *Advanced Learning Technologies, 2009. ICALT 2009. Ninth IEEE International Conference on*, pages 215–217. IEEE.