Creating Resilience – A Matter of Control or Computation?

Resilience Engineering explored through the lenses of Cognitive Systems Engineering and Distributed Cognition in a patient safety case study

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2013-11-11

Master’s thesis in Cognitive Science
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ISRN nr: LIU-IDA/KOGVET-A--13/001--SE
Abstract

In recent years, the research approach known as Resilience Engineering (RE) has offered a promising new way of understanding safety-critical organizations, but less in the way of empirical methods for analysis. In this master’s thesis, an extensive comparison was made between RE and two different research approaches on cognitive systems: Distributed Cognition (DC) and Cognitive Systems Engineering (CSE) with the aim of exploring whether these approaches can contribute to the analysis and understanding of resilience. In addition to a theoretical comparison, an ethnographic healthcare case study was conducted, analyzing the patient safety at a pediatric emergency department using the Three-Level Analytical Framework from DC and the Extended Control Model from CSE, then conducting an RE analysis based on the former two analyses. It was found that while the DC and CSE approaches can explain how an organization adapts to current demands, neither approach fully addresses the issue of future demands anticipation, central to the RE perspective. However, the CSE framework lends itself well as an empirical ground providing the entry points for a more thoroughgoing RE analysis, while the inclusion of physical context in a DC analysis offers valuable insights to safety-related issues that would otherwise be left out in the study of resilience.
Acknowledgements
This master’s thesis was completed through the help of many great people, which I owe an even greater thank you. First of all, Carina Skoglund and Åsa Lundberg at Linköping University Hospital made it possible to conduct the case study at the Pediatric Emergency Department, and all members of the department staff patiently answered my naïve questions regarding their workplace. Naturally, I also wish to thank my supervisor Magnus Bång for coming up with the original idea to this study and for the constant enthusiasm when guiding my work efforts. My friend and fellow master student Jonas Rybing also contributed to many interesting discussions over many a cup of coffee. Finally, special thanks go to Johanna for always supporting me and for enduring my long absence.

Tomas
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1 Introduction

Safety – a concept whose substance and importance is probably appreciated by everyone, but that nonetheless has proven to be problematic both to define and to improve. How can it be measured? When is it good enough? When is it possible to sacrifice safety to reach higher levels of efficiency, and conversely and more importantly, when is it necessary instead to keep a higher safety margin?

In an effort to work around these issues, safety research has during the latter part of the 20th century focused on studying accidents, situations where safety apparently was not good enough (Hollnagel, 2004). By understanding the causes of accidents, it might be possible to learn how they can be prevented, thereby increasing safety. However, a number of problems follow with this approach. First of all, finding the cause to an accident is not that simple – was it because of a deficit in a machine, a human error, or perhaps related to some flaw in the larger organization? In many cases, it does not really make sense to talk about one or a few causes to an accident at all, but rather to consider accidents as complex combinations of a number of factors. Furthermore, studying past accidents is of limited use since accidents are rare and unique – the next one might be entirely different, making previous safety measures ineffective (Hollnagel, 2010a). Indeed, some safety measures might even contribute to new kinds of accidents!

1.1 Safety as Resilience

In recent years, a novel approach to safety research bearing the name Resilience Engineering, RE, has challenged the traditional focus on analyzing past accidents (Hollnagel et al., 2006). Arguing that accidents are essentially the flip side of successes, proponents of Resilience Engineering suggest that safety research must study not only what goes wrong, but also what goes right (Hollnagel, 2010a). Safety is not simply seen as a stable state of no accidents, but as a dynamic process of adjusting and planning to keep a system within acceptable boundaries. The ability to do so despite external disturbances has been coined resilience (Hollnagel, 2006). For an organization to be resilient requires it to be proactive rather than reactive, constantly assessing the necessary tradeoffs between conflicting goals, and to reflect upon where the organization is positioned in the tradeoff-space and where it should be heading in order to be able to meet future challenges (Woods, 2010). In the most recent major publication on the research approach, Resilience Engineering in Practice: A Guidebook (Hollnagel et al., 2010), the concept was clarified further by introducing four underlying abilities contributing to resilience. These abilities are responding to real-time events, monitoring safety indicators to prepare proper responding, anticipating potential future events to guide monitoring as well as learning from past events to advance each of the other abilities. An organization needs to be proficient in each of these abilities in order to possess a potential for resilience, however resilience itself cannot be measured directly (Malakis & Kontogiannis, 2010).

1.2 Resilience – control or computation?

The four abilities contributing to resilience were a welcome addition to the Resilience Engineering research perspective, providing it with a more concrete way of describing its core concept. The publication of Resilience Engineering in Practice: A Guidebook (Hollnagel et al., 2010) furthermore put heavy emphasis on empirical studies, discussing each ability in connection to various real-life examples from safety-critical domains. Resilience Engineering might thus be said to have left its infancy, beginning to produce its own research findings described by means of its own independent theoretical concepts. Nonetheless, the approach is still new and the validity of those concepts is
relatively untested. Furthermore, it should be pointed out that no specific analysis method is connected to the RE approach – as mentioned above, only the potential for resilience is said to be measurable, and the four abilities contributing to resilience does not in themselves say much about how this abstract potential is realized in an actual organization. In order not to apply these abilities to a study entirely ad hoc, then, an empirical analysis method of some other research approach needs to be utilized, leaving the question: Which approach?

The natural choice here ought to be Cognitive Systems Engineering, CSE (Hollnagel & Woods, 2005). CSE was developed by the central researchers of Resilience Engineering and is in many ways the ideological forerunner of the new approach, although more broadly oriented towards the study of control in context rather than of safety. Indeed, some of the studies included in Resilience Engineering in Practice: A Guidebook successfully utilize concepts lifted from the CSE literature: A control model is used to describe safety management (Wreathall, 2010), the Functional Resonance Analysis Method (FRAM) present in CSE is here employed to illustrate the relationships between the four abilities contributing to resilience (Hollnagel, 2010b) and the Efficiency-Thoroughness Trade-Off (ETTO) principle (Hollnagel, 2009), pertaining to how people cope with high pressure by sacrificing thoroughness for efficiency, is mentioned frequently throughout both research approaches. This theoretical development brings with it a risk, however: What if Resilience Engineering, fueled by Cognitive Systems Engineering, proceeds to become disconnected to other well-established theories? It would certainly be undesirable to add yet another venture into safety research, if it had no touch points to earlier fruitful approaches whose efforts could be of great benefit in advancing it further. One such approach is Distributed Cognition, DC (Hutchins, 1995a), which just like CSE emphasizes the importance of context, but which has taken another direction towards the general study of cognition as computation, distributed across people, tools and environment. Seeing that the proponents of CSE have distanced themselves from this direct study of cognition (Hollnagel & Woods, 2005), it would certainly be informative to see what DC can contribute to the Resilience Engineering perspective on safety research.

### 1.3 Thesis aims

This Master’s thesis aims at making an extensive comparison between Resilience Engineering, Cognitive Systems Engineering and Distributed Cognition, thereby taking the first step towards a better understanding of what the latter two research approaches can contribute to the former. Beyond a mere literature review of each approach, I also present the results of an ethnographic case study in the safety-critical healthcare domain, analyzing patient safety at a pediatric emergency department using all three approaches. By doing DC and CSE analyses separately on an identical set of observational data and then doing a Resilience Engineering analysis based on the two former ones together, the contribution from each respective research approach to the understanding of resilience can be clearly demonstrated. The following questions arise:

- **What differences between Distributed Cognition and Cognitive Systems Engineering come to light when employed to analyze resilience?**
- **Are the differences entirely superficial, or do they have a decisive impact on the study of safety?**
- **Are there any aspects of Distributed Cognition or Cognitive Systems Engineering significant to the understanding of safety that are lost in the Resilience Engineering approach?**
Answering these questions will be greatly beneficial in informing Resilience Engineering of the insights from the earlier approaches, beginning to map out the relationship between the purportedly evasive resilience concept and the empirically rooted concepts of cognition as control and cognition as computation. More importantly, however, it will reveal any vital findings from Distributed Cognition and Cognitive Systems Engineering that would otherwise be left out completely of Resilience Engineering, thereby further strengthening an already promising new take on researching safety.

1.4 Delimitations
The Efficiency-Thoroughness Trade-Off principle has certainly been at play during the writing of this thesis, meaning that some interesting aspects of the safety research field were left out in exchange for a more streamlined study. Using more than one theoretical perspective to analyze a single case study is more thoroughgoing than usual, but certainly there were alternatives to Distributed Cognition, Cognitive Systems Engineering and Resilience Engineering that I will gladly let other researchers examine in the future, both in healthcare and in other safety-critical domains. The case study itself included a total of 14 observations during slightly less than one month (see section 3.5, Data collection and analysis), and although this period was sufficient for an extensive analysis, it meant that no consideration could be taken to longitudinal aspects of the case. Moreover, there is naturally no real end to the amount of possible data that can be gathered – here, my priority lay on providing a complete, broad analysis for all of the three research perspectives, rather than giving elaborate accounts of details. The time given did not allow for any video recordings, which would have provided a deeper level of detail but which would have been equally laborious to analyze.

1.5 Abbreviations
A number of abbreviations commonly found in healthcare as well as some lifted from the theoretical approaches in question are used throughout the thesis. These are all spelt out here.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ABCDE</td>
<td>“Airway”, “Breathing”, “Circulation”, “Disability” and “Exposure”. A mnemonic for the priority of essential steps when treating a patient – each step must be treated in that order for the next to be effective. Also exists in other variations with only the first letters included, or with more letters added for subsequent steps in treatment.</td>
</tr>
<tr>
<td>CAAU</td>
<td>Child Acute Assessment Unit</td>
</tr>
<tr>
<td>COCOM</td>
<td>Contextual Control Model (CSE term)</td>
</tr>
<tr>
<td>CSE</td>
<td>Cognitive Systems Engineering</td>
</tr>
<tr>
<td>DC</td>
<td>Distributed Cognition</td>
</tr>
<tr>
<td>ECOM</td>
<td>Extended Control Model (CSE term)</td>
</tr>
<tr>
<td>ER</td>
<td>Emergency Room</td>
</tr>
<tr>
<td>ESS</td>
<td>Emergency Symptoms and Signs (part of METTS, see below)</td>
</tr>
<tr>
<td>ETTO</td>
<td>Efficiency-Thoroughness Trade-Off (theoretical principle found in CSE and RE)</td>
</tr>
</tbody>
</table>
METTS Medical Emergency Triage and Treatment System. A tool for systematically prioritizing the treatment of patients. The case study in this thesis discusses a newer version intended specifically for pediatric care, called “metts-p”.

MR Medical Record. Throughout healthcare literature, Electronic Medical Record is commonly abbreviated “EMR”, however this thesis also discusses the use of a paper-based “Emergency Medical Record”. To avoid confusion, the latter will be abbreviated “Emergency MR” and the former “Electronic MR” throughout the following chapters.

PED Pediatric Emergency Department

RE Resilience Engineering

S-BAR “Situation”, “Bakgrund” (Background), “Aktuellt tillstånd” (Current state) and “Rekommendation” (Recommendation). Guideline for structured verbal reporting within the Swedish healthcare domain, indicating in which order information regarding a patient should be communicated.

1.6 Clarifications

The term emergency is somewhat ambiguous, since many patients arriving at an emergency department might not actually be in a state of true emergency, such as a cardiac arrest. The term is nevertheless sometimes used to indicate that a patient was not expected and that care should be given as soon as possible. Throughout this thesis, the term “emergency care” refers to treating actual life threatening health states. In contrast, “acute care” will be used to signify treatment of patients with health states that are not immediately life threatening, as seen also in the use of the term Child Acute Assessment Unit (CAAU), where such patients are admitted.

The term monitoring appears in two completely separate contexts in this thesis: Within the Cognitive Systems Engineering approach, it is used to denote one of the intermediate control-levels in the Extended Control Model (ECOM) devised by Hollnagel and Woods (2005), and within the Resilience Engineering approach, it is the term used as one of the four main capacities necessary for resilience in an organization (Wreathall, 2010). Despite the close link between the RE and CSE research approaches, these two meanings of the term “monitoring” are different and should not be confused.

Since the case study of this thesis was conducted at a Swedish hospital, I encountered some terms common in the Swedish healthcare system that did not exactly match any English equivalent. For instance, the Swedish professional title “undersköterska” refers to a person holding a specific education and having certain authorities, lacking an exact equivalent in healthcare systems of English-speaking countries – it has been translated into “nursing assistant”. The Swedish title “sjuksköterska” has been translated into “registered nurse” or simply “nurse”. All nurses and nursing assistants are collectively referred to as the “nursing staff”.

All quotes appearing in the analysis chapters of this thesis have been freely translated from Swedish, and in some cases, information about the identities of patients or staff members have been left out. Otherwise, the quotes are unaltered in terms of content.
1.7 Thesis outline and recommended order of reading

Following this introduction, chapter 2 provides a theoretical background of the three research perspectives used in the thesis, starting off with Distributed Cognition, then Cognitive Systems Engineering and finally Resilience Engineering before comparing each perspective to one another. The background to the issue of safety in the healthcare domain can be found in chapter 3, Conducting a healthcare case study, where I also demonstrate how the use of ethnographic methodology is motivated by the views of the research perspectives in question and describe the process of selecting, studying and analyzing the case study of the thesis. Following this description, each analysis of the case is presented one by one. Chapter 4, The Pediatric Emergency Department, serves as a general introduction to the case, describing its physical locations, work roles and tasks. Then follows chapter 5, Distributed Cognition analysis, chapter 6, Cognitive Systems Engineering analysis and chapter 7, Resilience Engineering analysis. Finally, I lift the summarized findings from the case study analyses to an abstract level in a discussion of their relevance to the research perspectives in general in chapter 8, ending with the conclusions of the thesis.

Scholars with an exclusive interest in the generalized comparison between the different research perspectives are advised to read chapter 2, Theoretical background, and then proceed directly to chapter 8, Discussion. For readers primarily interested in the healthcare case study, chapters 3-7 should instead be at focus, possibly preceded by section 2.1 through 2.3 if the theoretical perspectives are unfamiliar. The analyses in chapters 5 and 6 can be read in any order, although they both depend on the introductory chapter 4 to have been read beforehand. The Resilience Engineering analysis of chapter 7 is partly based on the previous two analyses.
2 Theoretical background

Beginning the comparison between the three research perspectives at focus in this thesis, Distributed Cognition, Cognitive Systems Engineering and Resilience Engineering, this chapter presents the background of each perspective in that order before comparing the main theoretical differences between each of them. Despite the differences that I will discuss ahead, however, all of these research approaches in fact have a common theoretical ancestor in the research approach known as Situated Cognition, which makes a brief historical description of this precursor a suitable starting point.

During the late 1980s, Situated Cognition began with an idea gaining ground that human activity should be studied in naturally occurring contexts, rather than using the methods from laboratory psychology which focused on studying the isolated minds of individuals. In the field of anthropology, Suchman (1987) proposed a theory of situated actions where the ad hoc nature of human activity is recognized to properly understand how implementation of plans is affected by changing circumstances, while Lave (1988) emphasized situated learning, and how different communities of practice form social entities in which rules, routines and vocabularies evolve to guide the behavior of participants. From a computer science perspective, Winograd and Flores (1986) provided a more linguistically oriented take on human action, stating that “Nothing exists except through language” (p.68) and that the meaning of language is fundamentally socially situated, making interpretation the very foundation of cognition. Common for all of the new ideas was a reaction against the prevalent model of human thinking. This mutual foe went under many names: the “rationalistic view” (Winograd & Flores, 1986), the “functionalist view” (Lave, 1988) and the “computational/planning model of action” (Suchman, 1987), however they all pertained to a model inspired by the advent of computers, where human cognition is seen as a set of computations on formal symbolic representations of the world taking place inside the head of an individual. Based on these computations, plans are formed, serving as precise descriptions of sequences of actions.

In an effort to distance Situated Cognition from the traditional model, its researchers placed focus on studying human actions themselves, and the situational circumstances impacting them (Artman & Waern, 1995). According to Suchman (1987), a plan may be implemented in an indefinite number of ways depending on circumstances, and therefore the focus of analysis should be the observable actions themselves, not the beliefs, desires or intentions lying behind them. This standpoint has garnered criticism, however, since it leads to unwillingness to generalize research results, instead providing detailed analyses of the ways in which work tasks are carried out in different unique settings (Garbis, 2002). Furthermore, Nardi (1995) argues that “Situated action models have a slightly behavioristic undercurrent in that it is the subject’s reactions to the environment (the ‘situation’) that finally determines action.” (p. 81). Although proponents of Situated Cognition did not deny the existence of internal mental states, leaving them out of the theory altogether proved to be problematic.

2.1 Distributed Cognition

The groundbreaking aspect of Edwin Hutchins’ theory of Distributed Cognition, DC (1995a), therefore, was not the claim that cognition should be studied in naturally occurring contexts, common with Situated Cognition. Rather, the novelty of the DC approach is to actually keep the model of cognition as computation on formal symbolic representations and instead redefine the unit of observation onto which this model is applied. Hutchins argues that cognition is distributed
across both people and their environment, and that the original basis for the model of human cognition was the socio-cultural system, where culture, context and history are fundamental aspects. However, as the idea grew that cognition was something that happened entirely inside the head of an individual, these aspects had to be left out of the picture. Instead of making an “extension” to the representational model by adding these external aspects, Distributed Cognition goes back to using the representational model to describe the whole socio-cultural, cognitive system itself. This brings the advantage of making cognitive processes open for direct study: “With systems of socially distributed cognition we can step inside the cognitive system, and while some underlying processes (inside people’s heads) remain obscured, a great deal of the internal organization and operation of the system is directly observable” (p. 129). Cognitive processes should be seen as performed by the cognitive system as a whole, clearly demonstrated by the suggestive title given to an article about speed memorizing in airliners, How a Cockpit Remembers Its Speeds (Hutchins, 1995b). Psychological terms such as memory that traditionally have been associated with individual persons are instead applied to systems of people and tools. This is not seen as the least problematic by Hutchins, stating that “the language we use for mental events is the language we should have used for these socio-cultural systems to begin with.” (1995a, p.364).

2.1.1 Cognition as computation and tools
Applying the “principal metaphor of cognitive science – cognition as computation” (Hutchins, 1995a, p. 49) to the cognitive system, the object of study becomes the transformation of formal symbolic representations between the system parts, people and tools, in order to perform a given task. Information is processed both bottom-up, from world to representations (i.e. when plotting a geographical position on a map), and top-down (when using the map to learn about obstacles in front). Tools are essential parts of cognitive processes, typically functioning not merely as ways to amplify certain abilities, but rather to transform a task by re-representing it, facilitating its implementation. Tools are also important in that they reflect the culture that created them, and the way of representing various aspects of the world that follows with that particular culture. In Hutchins’ words, “A way of thinking comes with these techniques and tools.” (p. 115). Commonly, a difficult computation that is frequently used will be embedded in a tool, creating a ready-made precomputation to make the task easier. Looking at the history of how a certain tool came about reveals the alternative ways in which a problem could have been solved to reach other representations. It should be noted that Hutchins avoids the term “artifact”, instead preferring “tool” to emphasize that it does not have to be a physical object created for a certain purpose, but can also be other parts of the environment as well as mental tools used internally in the head to support thinking. Later on, the researcher has also explored in greater detail how people use their own bodily motions as tools for thinking (Hutchins, 2010), adding an embodied view on cognition to the research perspective.

2.1.2 Forms and meaning
It might be appropriate to briefly discuss the consequences of adopting the metaphor of cognition as computation on formal symbolic representations as the basis for Distributed Cognition. With the “Chinese Room experiment”, John Searle (1980) famously illustrated how formal symbol manipulation is not sufficient for an actual understanding of what the symbols constitute, by likening the manipulation process to a person sitting in a room and successfully answering questions written in a foreign language (Chinese) only with the aid of formal rules for how to manipulate the foreign symbols. Hutchins (1995a) has a different interpretation of the Chinese Room, however: Seen as a socio-cultural system including both person and tools, the room does
actually have the cognitive properties to communicate in Chinese. At a first glance, this argument seems to be yet another restatement of what Searle (1980) called the “systems reply”, and to which the author devised a simple counter-argument already in the original paper: In principle, it should be possible for the person in the room to memorize all the rules for formal symbol manipulation, thus internalizing the complete system without achieving anything new in terms of understanding, knowing “only that ‘squiggle squiggle’ is followed by ‘squoggle squoggle’.” (p. 419)

However, Hutchins’ (1995a) interpretation of the computational metaphor emphasizes the fact that symbols always have some physical realization, constraining how they might be manipulated. Although never stated explicitly, this could be seen as a tacit assumption that the purely formal aspect of symbol manipulation is left out of the computational metaphor as seen by Hutchins: The meaning of symbols is embedded in the culture that shaped them into their physical forms, and these representations constitutes the only natural way for a member of that culture to comprehend the world. Indeed, Hutchins (1995a) argues that the form and meaning of a representation often are indistinguishable – an object is actually on a certain position on a map in the mind of the map’s user. Regarding the exact nature of this internal representation of meaning, however, the author remains cautious.

2.1.3 Coordination and communication

The computational process in a cognitive system is not only affected by the cultural history of tools and how they shape thinking, however, but also by the physical distribution of tools and allocation of tasks (Hutchins, 1995a). Typically, several people perform different activities in parallel, spread out over space and time, meaning that there is a need for coordination between the system parts. According to Hutchins, coordination is “to set oneself up in such a way that constraints on one’s own behavior are given by some other system.” (p. 200). This means that coordination comes from the structure of the cognitive system itself, not so much from an individual performer. Activities are often guided into sequences by certain actions disabling others, and when parallel activities risk interfering with one another, information buffers are useful ways to temporary store information later to be propagated through the system. The structure of the cognitive system needs not to be static, however: Kirsh (1995) observed that people frequently demonstrate an “intelligent use of space”, organizing the physical layout of objects to reduce time and memory demands. Hutchins (1995a) also argues that the social organization of people is crucial for coordination: Pre-defined work roles determine the division of labor between people, often dividing responsibilities over certain sub goals of the overall task. Often some type of social hierarchy is formed, where a kind of human interface is created between people on lower positions gathering information and people higher up integrating the information and making decisions.

The nature of communication between people structures the representations propagated through the system: Subtle cues can often be found in social messages, and the meaning of a message is tightly connected to the context in which it is produced. Rich communication brings with it greater robustness, enabling more diverse interpretations of situations with input from many people. In settings where tasks are widely distributed over space or time, people will not have the same insight into each other’s tasks, making communication necessary but also more prone to misunderstandings. Tight workspaces might lead to increased information interference and need for information buffers, however. In some cases, structured communication such as cross-check procedures, where a message is repeated, are used to create a context where misunderstandings are easier to detect (Hutchins, 1995b).
2.1.4 Distributed Cognition analysis: The Three-Level Analytical Framework

With a theory spanning both close examination of representational states as well as cultural, historical and communicative aspects of how the transformations between these states are coordinated, an analysis of a cognitive system should be required to be both detailed and widely comprehensive. Adopting a framework originally devised by Marr (1982) to describe the computational process of vision on three levels of detail, Hutchins (1995a) argued that such a framework could just as well be applied to describe the computational task of a larger cognitive system. Named the “Three-Level Analytical Framework” by Garbis (2002), the first level is functional, describing the overall goal of the system, its division of labor and the typical, by-the-book procedures that the system performs to achieve the overall goal. This level might also include historical accounts of the system. The second level is representational, providing a description of the representations of information and how they are propagated and transformed across people and tools, as well as the structure of system parts coordinating the information flow and the social organization guiding communication. Finally, the third, implementational level deals with how representations are realized in system parts, typically providing descriptions of the representational transformations between a single person and a tool for a detailed account of the cognitive task. With these descriptions of three levels of detail, Garbis argues that the framework can explain how the actions on different levels interact and are brought into coordination in order to accomplish the overall goal of the cognitive system.

2.2 Cognitive Systems Engineering

About the same time as Edwin Hutchins started to take interest in the distributedness of cognition, Erik Hollnagel and David D. Woods laid the ground to a parallel research approach with the publishing of Cognitive Systems Engineering: New wine in new bottles (1983). With both authors previously engaged in research on process control in the nuclear energy domain, Cognitive Systems Engineering, commonly abbreviated CSE, had its roots in the field of human-machine interaction. Hollnagel and Woods noted that as machines got increasingly complex, they no longer served only to amplify the physical capabilities of people but also got more involved in aiding intelligent behavior. However, the development of so-called Man-Machine Systems was still focusing exclusively on the physical, logical world, with a limited understanding of psychology, leading to a problematic mismatch between man and machine. The authors’ proposed “new wine” was the idea to view the Man-Machine Systems as cognitive systems: intelligent, goal-oriented systems using knowledge of the world to plan ahead and adapt to changing conditions. The “new bottles”, on the other hand, was the emphasis to study the functioning of the system as a whole, where the constituents cannot be substituted without changing the overall behavior of the system.

2.2.1 From interaction to coagency

Interestingly, CSE originally embraced the theory of cognition as computation, stating that a cognitive system was based on symbol manipulation (Hollnagel & Woods, 1983). The dominant information processing model of the time was criticized, however, for limiting cognition entirely to predetermined sequences of bottom-up processes, not recognizing the influence previous understanding has on behavior. As the CSE approach developed over time, it gradually focused more on the study of the overall functioning of a cognitive system, and the information processing paradigm started to feel ill-fitting (Hollnagel & Woods, 2005). Studying information processing, it seemed, easily led to getting lost in understanding the human-machine interaction with an interface, while the real issue at hand, how the human-machine coagency enabled control of a process through an interface, was forgotten. In the words of Hollnagel and Woods, “Although
coagency requires interaction, it does not follow that it can be reduced to that.” (2005, p. 13). The notion of joint cognitive system was introduced, signifying two or more cognitive systems working together to achieve a common goal.

2.2.2 Cognition as control

Adopting a functionalist perspective, the CSE approach defines a cognitive system based on what it does, rather than what it is in terms of its structure (Hollnagel & Woods, 2005). This has the interesting implication that as long as a system displays intelligent behavior, it is assumed to be cognitive. A human is by definition a cognitive system in this regard, while a machine might be considered an artificial cognitive system – seen together, the human-machine coagency forms a joint cognitive system. As long as there is at least one human involved in the system, it can reasonably be assumed to possess cognitive abilities. However, Hollnagel and Woods argue that CSE is actually not concerned with studying cognition per se, stating that “the continued use of the term cognition is more than anything else due to terminological hysteresis.” (p. 59). Instead, the authors propose that the central object of study should be how a joint cognitive system exerts control of a process. The concept of control is retrieved from the field of cybernetics, where it is defined by Ashby (1956) as keeping the variety, or possible states, of a target system within a predefined performance envelope. This is achieved by the regulator of the system. In order to maintain control, Ashby stated that the variety of the regulator must be at least equal to the variety of the target system, known as the Law of Requisite Variety. Conant and Ashby (1970) later added that a good regulator needs to be a model of the target system, which would mean that the internal variety of the regulator and the external system variety are equal. With these ideas applied to CSE, the study of cognition was reinterpreted as the study of controlling the variety of joint cognitive systems (Hollnagel & Woods, 2005). Seeing the human or humans in a joint cognitive system as its regulator, or controller, it followed that a mental model of the system was needed in order to maintain control. Interestingly, this requires some sort of internal representation of the world, however the authors do not delve deeper into the exact specifics of its realization on a cognitive level, but note that it needs to be complex enough to adequately account for the complexity of the system.

2.2.3 The importance of context

Abandoning the information processing paradigm also meant that CSE could place more emphasis on the context in which a cognitive system is functioning. In the decades following the introduction of CSE as depicted by Hollnagel and Woods, the theoretical approach was influenced by the Situated Cognition perspective and its emphasis on studying naturally occurring activities. According to the authors, cognition should be seen as part of a stream of varying activity, where cognitive systems are embedded in a social environment constraining the activity and where persons make frequent use of artifacts to aid them (Hollnagel & Woods, 2005). Just like in the theory of Distributed Cognition, however, cognitive systems are seen as goal-driven, meaning that at least some level of internal mental states are included in a CSE analysis to counter any potential accusations of behaviorism such as those directed against Situated Cognition (see the introduction of this chapter). Furthermore, the authors are careful to note that although the CSE approach proposes that the environment must be accounted for when studying cognition, it is critical to be able to make generalizations: “The risk of observation in context is that the observer quickly can become lost in the detail of particular settings at particular points in time with particular technological objects.” (Woods & Hollnagel, 2006a, p. 4) The aim of CSE, therefore, should be to
extract abstract patterns of system functioning over several observations in various domains, making the approach more predictive than descriptive in nature.

2.2.4 Cognitive Systems Engineering analysis: The COCOM and ECOM

As a way of modeling cognition as contextual control, Hollnagel and Woods (2005) present the Contextual Control Model (COCOM). The model is cyclic (see Figure 2.1), depicting control as a continuous effort to keep a process within some given boundaries by evaluating new events to choose and execute control actions. Although the authors do not deny that this activity involves some kind of information processing, the information in terms of cybernetics is seen as feedback provided from changes to the system state. Apart from control, two important concepts in the COCOM are construct and competence. The construct is closely linked to the concept of a mental model of the controller. It refers to the current understanding of the process, modified by evaluating new events/feedback in order to choose the proper control actions in the current context. The construct might also be aided to varying degrees by feedforward, bypassing the actual changes to the system state to account for the anticipated changes – an important part of control that Hollnagel and Woods point out often is forgotten. Competence refers to the possible control actions that can be applied to a given situation. Both construct and competence are necessary in order to exert control: With an inadequate construct, improper control actions might be chosen that will lead to a worsened situation, and lacking the necessary resources to build a competence, it might be impossible to execute the proper control actions.

In a typical complex cognitive system, Hollnagel and Woods (2005) note that control will be exerted on multiple layers of detail simultaneously. In order to account for this, the authors propose a development of the COCOM called the Extended Control Model (ECOM). This model

![Figure 2.1. The cyclical control process. Adapted from Hollnagel and Woods (2005).](image-url)
describes the performance of a joint cognitive system as several control-loops, each in effect equivalent to a COCOM with separate input, construct and control actions. In keeping with the pragmatic functionalist view, the number of control-loops should not be pre-determined but instead customized to account for the degree of variability of the system that one wishes to describe, making the model applicable to a wide range of settings in different domains. When exemplifying the use of the model, however, Hollnagel and Woods present four loops named targeting, monitoring, regulating and tracking as seen in Figure 2.2 below:

![Figure 2.2. The Extended Control Model. Adapted from Hollnagel and Woods (2005).](image)

*Targeting* refers to the control-loop at the longest time-scale, where the overall goal of the activity is set. According to Hollnagel and Woods (2005), targeting is an open-loop control activity (based only on feedforward) in the sense that the outcome of control actions are complex and indirect, depicted in Figure 2.2 by the dotted arrow in the loop. The targeting activity provides goals or targets for the *monitoring* control-loop, where plans on an intermediate time-scale are set. These are in turn realized at the *regulating* control-loop, which is the lowest level of conscious control where plans are implemented as contextually specific short-term actions. Below the regulating level is the *tracking* level, where routine operations are carried out in an unattended manner. The tracking level is entirely feedback-driven (closed-loop) and in practice does not involve more than one individual (if not completely automated by technology). This means that it might be considered too detailed to include when studying a larger system function, such as in the case of an ECOM analysis of organizational planning by Gauthereau and Hollnagel (2005).
Between the layers in the ECOM model, several interdependencies exist (Hollnagel & Woods, 2005): In Figure 2.2, the goals and targets provided by each layer to the next are visualized by the gray arrows, but there are naturally other relations between the control-loops, such as feedback. The model can easily be applied to account for a goal hierarchy, where low-level goals are controlled mainly through compensatory control (feedback) and higher level goals mainly with anticipatory control (feedforward). Hollnagel and Woods describe how control might be lost at one or more levels without affecting the other: When driving a car, for instance, having to break at a sudden danger might interrupt the tracking activity but will not affect the targeting level since the overall goal of the driving is still the same. In a larger joint cognitive system, different people will probably be involved in activities at different levels to various extents, and temporary loss of control at one level might even go unnoticed by those not directly engaged in the activity.

2.3 Resilience Engineering

The term “resilience” has been introduced in a number of research fields to describe the ability to recover from some disturbance. Commitment to resilience has been cited as one of the properties of High-Reliability Organizations (Weick & Sutcliffe, 2001), and the term was also introduced in the CSE literature, described by Woods and Hollnagel as one of the main patterns of the research approach (2006a). The “founding fathers” of CSE then went on to lay the ground to the safety research approach known as Resilience Engineering, abbreviated RE. In RE, the notion of resilience is used to describe “the ability of a system or an organisation to react to and recover from disturbances at an early stage, with minimal effect on the dynamic stability.” (Hollnagel, 2006, p. 16). The dynamic character of performance is important in the RE approach, where performance variability is seen as the origin of both failures and successes (Woods & Hollnagel, 2006b). Recognizing that the performance variability of an organization is closely linked to the nature of human work, the RE perspective argues that human adaptability and flexibility are crucial contributors to resilience. Furthermore, it is claimed that earlier safety paradigms have been too solely focused on the study of failures that should be eliminated, which reduces the adaptability of the system and makes it brittle. Examining failures in hindsight also does not necessarily provide a good way to measure safety – if the number or adversity of past accidents decreases, the perceived feeling of safety might motivate decreased safety efforts, making an organization less prepared for future events. Instead, Woods and Hollnagel argue that safety in a resilient organization is a “core value, not a commodity that can be counted.” (p. 6). Adopting this view, the absence of accidents is instead met by the organization with a continuous strive to cope with ever-changing circumstances. Hollnagel (2008) later expanded further on this dynamic character, stating that “safety is something that an organisation does, rather than something an organisation has. In other words, it is a process rather than a product.” (p. 64). Woods (2006) discusses how typical success stories in safety research will tell of some individual who suspects a critical flaw in a safety-critical system, insisting that production should be stopped and thereby preventing a major accident and being praised by the organization as a hero. However, as Woods points out, it would be more interesting to observe the reaction if there was actually no flaw: A resilient organization would still praise the risk awareness of the individual, acknowledging that production goals must sometimes be sacrificed for the benefit of maintaining safety margins. The challenge, of course, is to know in which situations this sacrifice is necessary.

According to the proponents of the research approach themselves, Resilience Engineering was initially met with some skepticism regarding whether or not it really brings something new (Hollnagel et al., 2008). The subsequent answer is that RE does provide a novel way of looking at
safety, however a point is made not to reject all existing methods of safety analysis. Instead, well-established techniques can be useful to study resilience in an organization, but they should be viewed in a new light. RE therefore has not been explicitly connected to any specific analysis methods in particular, even though there are close ties to CSE as discussed in section 1.2. Furthermore, the most recent anthology on the RE approach is titled Resilience in Practice: A Guidebook, providing numerous examples of real-life cases of studying resilience in safety-critical systems (Hollnagel et al., 2010). To better be able to understand the new concepts, four main factors contributing to resilience have also been identified: these are the abilities of responding, monitoring, anticipating and learning. These abilities are described as interdependent, meaning that possessing all of them is necessary to have the potential for being resilient. In the following sections, each ability is explored in greater detail.

2.3.1 Responding: Dealing with the actual

The ability to respond refers to the capacity of a system to adapt to the current demands of a situation, dealing with the actual (Pariès, 2010a). This refers to activities both at the sharp end, where the situation is assessed and proper responses are carried out, as well as the blunt end, where issues such as maintaining resources in terms of equipment and people are dealt with in response to real-time events. One strategy for building a capacity to respond is by devising ready-to-use solutions to specific situations that are known to occur in a system. Pariès (2010b) points out that some situations, such as so-called “bird strikes” in the aviation domain, might be extremely rare and totally unexpected by operators working at the sharp end, but still well known at a system level, meaning that specific solutions can be devised (for instance strengthening the windshields of airliners). However, even this ability to foresee future events is limited, and such solutions will need to be complemented with ad hoc adaptations devised on the spot by operators. Pariès stresses that this adaptive skill requires generic competence in a team of operators, such as efficient communication, assessing the possible options in a situation as well as a common sense to determine when procedures should be adhered to and when they must be abandoned. The key to achieve this is through training, which is further emphasized by Bergström et al. (2010). The authors suggest that generic competence is best achieved by designing training scenarios that simulate a novel situation, where the operators are forced to go outside the boundaries of their ordinary roles of their team. Furthermore, the scenarios should be difficult enough that consequences of actions are hard to foresee, and the situation should be escalating, leading to increased demands on the coordination of the team and possibly prompting a need to switch strategies.

2.3.2 Monitoring: Dealing with the critical

As mentioned in section 1.6 in the Introduction chapter, the term monitoring is used both in the CSE literature as a level in the ECOM as well as in RE to describe one of the main abilities of resilient systems. In this latter sense, monitoring refers to the ability to deal with the critical, that is, to observe vital safety indicators in order to properly be able to respond to critical changes (Wraithall, 2010). Such indicators can be both leading, meaning that they point to some event to take place in the near future, or lagging, informing about a past event. In larger organizations, however, Wraithall notes that lagging indicators on a local scale can serve as leading indicators for systemic changes. Many times, indicators are nothing more than “faint signals” foreboding a potential accident. Often there exist no explicit models for identifying such warnings, operators instead having to rely on their experience. This was explored in greater detail in the previous work by Klein et al. (2005) regarding the related concept of problem detection, where it was argued that
expertise gives a sense of typicality against which situations can be measured to better detect subtle cues of anomalies. However, Klein et al. also noted that experts are keener on explaining away any data conflicting with their expectations, sometimes leading to impaired problem detection when failing to revise the understanding of a situation. This suggests that experience alone does not guarantee adequate monitoring capabilities in an organization. Malakis and Kontogiannis (2010) argue that training general team competencies is key to effective monitoring, focusing on abilities such as shared situation understanding and communication of intent between team members.

2.3.3 Anticipating: Dealing with the potential
Whereas responding concerns dealing with actual real-time events and monitoring is trying to observe and interpret indicators of such events, anticipating concerns dealing with the potential events to take place in the future (Woods, 2010). It is arguably the ability most difficult to obtain, and according to Hollnagel, definitely the one on which the least effort has traditionally been put (2010b). From a Resilience Engineering perspective anticipating is crucial, however, in that it guides monitoring – with no ability to predict the future state of a system at all, it is extremely hard to know what indicators to look for, of course, limiting an organization to trial-and-error reactions. In the field of problem detection, Klein et al. (2005) discuss stance, a term encompassing factors such as alertness, level of suspicion and emotional status, which all influence the ability to detect problems. This suggests that a risk aware attitude aids monitoring, serving as a way to better anticipate possible indicators of dangers. Anticipating could also be seen as a form of self-monitoring in an organization, reflecting on its own behavior and proactively determining when this behavior needs to be changed. Woods (2010) depicts a set of necessary tradeoffs between an organization’s goals such as optimality-flexibility, efficiency-thoroughness and acute-chronic, and argues that a resilient organization must know where it is positioned in the space between these tradeoffs and where it needs to be to meet future demands. A number of ways in which this typically fails are presented, called “basic adaptive traps” (Woods & Branlat, 2010a). The first of these is working at cross-purposes – when a behavior is locally adaptive but globally maladaptive. This behavior might be avoided through the use of a polycentric control architecture (Woods & Branlat, 2010b), which means that a system has several control centers with some extent of autonomy, in contrast to an architecture employing consensus or a strict hierarchy. The control centers, however, should be interdependent and with some overlap between their authorities and responsibilities in order to make it necessary to balance between various sub goals. Tjørhom and Aase (2010) describe the goal balancing in terms of downward resilience, providing clear rules and goals from management, and upward resilience, letting operators use their experience and professionalism to handle the gap between rules and actual situations. The second basic adaptive trap described by Woods and Branlat (2010a) is decompensation – when a system continues to adapt to ever increasing pressure until its adaptive capacity is depleted and it suddenly collapses. To avoid this, the authors argue that people need to communicate their perceived workload in advance, to make sure that sufficient buffers are maintained. Finally, the last trap is to get stuck in outdated behaviors. A system needs to realize that a particular response strategy is no longer successful and that the situation understanding needs to be revised.

2.3.4 Learning: Dealing with the factual
In contrast to anticipating, the ability of learning concerns past events that did occur, and how to deal with the factual (Hollnagel, 2010a). According to Hollnagel, learning is necessary in order to develop all the other capacities: learning how to respond to new changes, which indicators that are
necessary to monitor and what kind of adapting that should be anticipated. Since the RE approach views performance variability as the origin of both failures and successes, the principle is to learn not only from what went wrong, but also from what went right. Safety should be understood as a “dynamic non-event” (Hollnagel, 2006), meaning that it takes effort from operators to continuously keep a process within acceptable boundaries. In this view, major accidents alone are insufficient as lessons for learning (Hollnagel, 2010a), since they are infrequent and allow for little opportunity to generalize knowledge as well as to know that the right lessons have been learned. Learning from what goes right brings with it the problematic issue of having to analyze too much information, however, since accident-free functioning of a system is (hopefully) the norm. Therefore, an incident reporting system is often employed, where operators write a report when they experience a smaller incident, or a situation that could easily have led to something more adverse. According to Pasquini et al. (2010), such systems need to be designed differently depending on the context in which they should be used. First of all, the criterion for which events that constitutes incidents, called the pass criterion, might be easily defined, but perhaps more often is less clear-cut. In such cases, reporting should focus on risks rather than incidents, and operators should be properly trained in how to determine the nature of various events. Furthermore, the degree of standardization influences the information that needs to be included in a report: In highly standardized organizations, a decontextualized description of an incident might suffice for further analysis, whereas organizations focusing on risk reporting probably will have to include some background knowledge as well. When analyzing reports, one must also take account of the visibility of details to the operator that wrote the report: Some important facts might have been omitted by or unknown to the operator, meaning that the description of the incident is incomplete. Pasquini et al. also point out that there is a need to understand the characteristics of the community: If there are a number of microcommunities in the organization consisting of people with different professions, a central reporting system is difficult to create and after analyzing an incident, the feedback to the operators should be quick and targeted to the right people in order to provide efficient learning. Finally, one must assess the safety culture of the organization, since it affects the feedback that can be offered as well as the type of analysis that should be carried out. A healthy safety culture might increase the willingness of operators to report incidents, while some organizations will require a high degree of anonymity for a reporting system to work.

2.4 A theoretical comparison

Concluding the theoretical background, in this section I compare the main differences between the three research approaches presented above, starting off with DC and CSE and finally comparing them both to RE.

Although it has been argued that the unit of analysis in DC lacks a specific name (Halverson, 2002), it is clearly a theory of cognition, seen as computation on representations distributed across a cognitive system. Seeing that practically any activity involving people and tools could be regarded as a cognitive system as understood by Hutchins, DC is a most general theory, and although it certainly can be used to study safety, this is only one of many possible areas of application. Garbis (2002) mentions that DC primarily is a descriptive theory, aiming at explaining the functioning of cognitive systems, while other related approaches such as CSE (here named “cognitive engineering”) tend to be more predictive. CSE certainly seems to have been developed with the long-term aim to be able to predict the behavior of cognitive systems, epitomized in the search for patterns of system functioning. The approach makes use of the term “cognitive system” in a way
similar to DC, but CSE is leaned towards studying larger, joint cognitive systems where functioning is “non-trivial”, where there is some degree of unpredictability and where resources such as time are limited (Hollnagel & Woods, 2005). Furthermore, the view of cognition as control does lend itself nicely to the study of safety, albeit that safety need not necessarily be a critical issue in such a system.

2.4.1 Views on cognition
The different views on cognition in DC and CSE, respectively, are essentially two clever workarounds to studying the human mind directly, reflecting the evasive nature of cognition. By adopting the computational metaphor on the socio-cultural cognitive system, Hutchins found a way to address cognitive capacities by observing system behavior; however, the DC perspective still remains “agnostic on the issue of representations ‘in the head’” (1995a, p. 129). Garbis (2002) argues that this stance is in fact not meant to avoid the question of how the mind works, seeing that cognition is believed to emerge first on the collective level and only then leaving residue in individuals – the collective level is thus the natural starting point for observation. Hollnagel and Woods, on the other hand, argue that CSE should not focus on the study of cognition per se at all, opting instead for the ability to exert control as the relevant aspect of system behavior (2005). The disinterest of cognition in favor of system functionality further means that Hollnagel and Woods remain critical to the use of the computational metaphor: Hutchins’ “Cognition in the wild” is seen as a commendable effort at going beyond the mind of the individual, however the maintaining of the information processing paradigm is seen as problematic from a CSE perspective since it reduces human-machine coagency to detailed accounts of representations, risking to lose the big picture in the process.

2.4.2 The role of artifacts
Another difference between the research approaches comes to light regarding their views on the role of artifacts. From a DC perspective, an ideal human-machine interface as expressed by Hollan et al. (2000) is one that provides a meaningful analogy between representations and the things they represent, guiding the user’s task in such a way that the next thing that should be done becomes apparent. This is seemingly well in accordance with the CSE principle of controlling a process through an interface, however it arguably conflicts with another basic tenet of the research approach, namely that human-machine interfaces should never act as “simplifications” by concealing the real complexity of a task, since that only serves to reduce the possible set of actions to keep control of the process (Hollnagel & Woods, 2005). In the functionalist CSE, an artifact is primarily seen as a means to accomplish a certain task, and although its way to represent the task might be of importance, it is only relevant in terms of how well it amplifies control for its operators. The DC perspective places more emphasis on the exact mechanisms for coordination between artifacts and people as well as the detailed implementation of representations, giving artifacts a more central role overall. This aspect of Distributed Cognition was criticized from an Activity Theory standpoint by Nardi (1995), who found the equivalence between human and artifact in the cognitive system to be illogical since artifacts cannot possess knowledge, only mediate human knowledge. Garbis (2002) defends this stance by clarifying that artifacts should only be seen as equal to people on the overall system level, where they are equally important in solving a task, while at the lower levels, “it should become clear that it is people who interpret and synthesize information.” (2002, p. 55). The main benefit of artifacts from a DC perspective is that they contain a residual of the culture that created them, bringing with them a way of thinking much like the mediating of knowledge as understood in Activity Theory. Hutchins notably avoids
the term “artifact”, preferring the more extensive “tool” which includes all kinds of culturally mediated coordinators of cognition, be they physical objects or mental thinking techniques. In this sense, DC not only goes into greater detail than CSE when studying the technology of cognitive systems, but also widens the analysis by bringing in factors such as history and culture.

2.4.3 The role of context
Nonetheless, it should be noted that such factors regarding the context of a cognitive system are present in the CSE approach as well. As mentioned in section 2.2.3, Hollnagel and Woods (2005) consider cognitive systems to be embedded in a social environment, constraining the stream of varying activity. However, Norros and Salo (2009) point out that it is unclear exactly how this social environment is supposed to be included in a CSE analysis. In fact, the emphasis on generalizing patterns from several observations makes the research approach relatively context-independent. In the Contextual Control Model (Hollnagel & Woods, 2005) presented in section 2.2.4, cognition is seen as “contextual” in the sense that it is manifested through control actions that vary with the situation at hand, in contrast to the classical information processing view of actions as mere output of entirely mental, decontextualized cognitive processes. This means that the social environment is taken into account when doing a CSE observation of a cognitive system, yet the description of the system itself is stripped of such information, leaving an abstracted control-loop model. This understanding of context is quite different from the one used in DC, where the physical forms of representations in the environment have culturally constituted meanings, making them highly relevant to include in the modeling of the cognitive system (Hutchins, 1995a). Both these research approaches are formulated generally enough to be used when analyzing a cognitive system of any size, although DC will tend to include both a lower, representational level as well as a higher, cultural level in the analysis, with CSE taking the middle ground.

2.4.4 Comparing RE to the theories on cognition
While Distributed Cognition was developed as a theory on all of cognition and Cognitive Systems Engineering is primarily inclined to studying cognition as control in complex systems, Resilience Engineering is the only approach that is directly concerned with safety, seen of course as the potential for having resilience. Although very close in spirit to CSE, this more specific focus of RE invites deeper analysis of organizations in safety-critical domains, such as healthcare, described more closely in section 3.2. The functionalist attitude of CSE is certainly kept in RE, where safety is seen as a process rather than a property. Moreover, the issue of cognition is entirely left out of the approach, leaving room instead for studying the organizational capacities that create the potential for resilience. These capacities are furthermore said to be interdependent, meaning that the organizational context in which they manifest themselves will inevitably be considered in the high-level RE perspective. At some level, it might be tacitly assumed that these organizational capacities stem from the cognition of individuals using artifacts, but such a level of detail is seemingly too fine-grained to be considered relevant. Of course, one of the central issues in this thesis is whether these low-level details discussed in CSE and DC might indeed be relevant to RE after all.

When compared to the other research approaches, Resilience Engineering is also less about the “here-and-now” behavior of a system or organization and more about the attitudes towards potential future dangers – Hollnagel and Woods (2005) introduced this line of thinking in CSE with the notion of feedforward, but RE goes further in the emphasis on anticipating as a crucial
organizational ability. Whereas CSE is concerned with how people compromise between different goals to cope with high pressure on performance, epitomized in Hollnagel’s (2009) Efficiency-Thoroughness Trade-Off (ETTO) principle, Resilience Engineering widens the perspective and notes that organizations must self-monitor their desired future position in a whole tradeoff space, where the ETTO principle only covers one of many necessary balancing acts (Woods, 2010). From this perspective, resilience has to do more with potential situations than actual situations, and it is in fact argued that the only thing that can be measured is the potential for resilience, not resilience itself (Malakis & Kontogiannis, 2010). Unfortunately, even organizations with great capacity for responding, monitoring, anticipating and learning will never be immune to accidents, but when a critical situation is reached, the potential for resilience will become evident and hopefully prove to suffice to prevent an adverse outcome.

Halverson (2002) suggests that a pragmatic evaluation of a theory’s benefits should assess four different attributes: its descriptive power, its inferential power, its application power as well as its rhetorical power (how well the terminology of the theory can be used when discussing the real world and mapping concepts onto it). Resilience Engineering brings a promising new way of describing safety and it applies well to safety-critical organizations. However, the purported evasiveness of the term “resilience” discussed above seemingly poses a problem for the theory when it comes to inferring the relevant underlying contributors to safety in an organization. Identifying the four capacities necessary for creating resilience helped to clarify the components of the term, thereby building a better rhetorical power, yet how these capacities might be realized by subsystems of organizations needs to be studied in greater detail. As noted in section 2.3, the proponents of RE are well aware of this, considering the approach to primarily bring in a new way of looking at safety and leaving it open as to which analysis method that is employed to study the underlying mechanics of resilience. This standpoint essentially makes RE an ideal platform for comparing the contributions of other research approaches, such as DC and CSE, when employing their respective analysis methods to the study of safety. In Table 2.1 below, the three research approaches presented in this chapter are summarized to provide a theoretical comparison between them. In the following chapter, I go into deeper detail on the ethnographic case study conducted in the healthcare domain to analyze the patient safety at a pediatric emergency department using all three research approaches.

Table 2.1. Summary of the theoretical differences between the three research approaches.
3 Conducting a healthcare case study

The comparison between Distributed Cognition, Cognitive Systems Engineering and Resilience Engineering presented in section 2.4 provides a firm theoretical description on how the research approaches differ in terms of their main interests, views on various terms, preferred levels of analysis and et cetera. My aim with this thesis, however, is to go beyond a pure literature review and supplement these insights with an empirical comparison, investigating how each research perspective applies to the study of safety from an identical set of observational data. In order to fulfill this aim, I conducted a case study in the healthcare domain, employing ethnographical methods to study safety at the Pediatric Emergency Department of Linköping University Hospital and then analyzing this data from the viewpoint of DC, CSE and RE, respectively. This chapter describes the views on ethnography from these research approaches, then proceeds to give some background to the issue of safety in the healthcare domain in general and finally describes the process of selecting, studying and analyzing the Pediatric Emergency Department.

3.1 Ethnographical methodology

According to Agar (2008), the goal of ethnography is not entirely easy to define, but the role of an ethnographer might be described as a “professional stranger” in a community, learning about the ways of its members by being part of it for a longer period of time and trying to gain communicative competence in order to understand the viewpoints of different members. No matter how elusive, however, ethnographical methodology is strongly advocated by the proponents of both Distributed Cognition and Cognitive Systems Engineering, making it a straightforward decision to use as the basis for gathering empirical data to this thesis. (RE does not, as noted before, recommend any particular research method, but its frontmen Hollnagel and Woods are by extension the same as for CSE). From a DC perspective, Hutchins (1995a) criticizes the traditional laboratory paradigm of cognitive science for constructing entirely hypothetical, decontextualized situations that are not representative of how human cognition really works. The author argues that if the type of challenging problem given to subjects in laboratories would ever have to be solved in real life, some form of work-around such as a tool would be devised to make the problem-solving easier to begin with. Coining the phrase “Cognition in the Wild”, also to become the title of the book first describing DC, Hutchins proposes a “cognitive ethnography” where these real-life solutions can be studied in real-life settings. This methodology was later described in closer detail by Hollan et al. (2000), said to involve a multitude of techniques such as interviewing, video recordings and participant observations. The latter is deemed especially important because the researcher must understand not only how information is processed in the domain under study, but also how subjects understand this information in the context of their local culture. From a CSE standpoint, Hollnagel and Woods (2005) share Hutchins’ advocacy of observing how people actually do problem-solving in naturally occurring contexts, however the authors are less specific regarding which exact techniques to use. Furthermore, Hollnagel and Woods feel that the notion “Cognition in the Wild” might be misleading, since it suggests that laboratory experiments are something entirely different when in fact they provide a type of context nonetheless, albeit an artificial one. This strand of thought appears in the DC literature as well, however, where Hollan et al. note that “An experiment is, after all, just another socially organized context for cognitive performance.” (2000, p. 182)

While ethnographical fieldwork is typically employed when studying culture in a wide sense in a large group of people (Creswell, 2007), the rationale for conducting a narrower case study was that
it would better fit the boundaries of the “cognitive system” concept found in DC and CSE. As pointed out in section 2.4.4, RE generally describes larger organizations than the former, but the approach still retains a relatively narrow focus on the single issue of safety, making a case study applicable. Furthermore, an analysis of resilience naturally needs to be conducted on a case within a safety-critical domain – this requirement is met by healthcare, as demonstrated in the following section.

3.2 Safety issues in the healthcare domain

Ten years ago, the American Institute of Medicine put up a list of six ambitious goals for the healthcare system: to be Safe, Timely, Effective, Efficient, Equitable and Patient-centered (2001). According to the World Health Organization (WHO), however, the number of patients worldwide that suffer injuries or death due to unsafe healthcare is still in the magnitude of tens of millions, meaning that the first goal is far from reached (2008). In a later report, WHO (2009) establishes that while developed countries have come far regarding the quality of medical competencies and equipment, the greatest remaining obstacles to patient safety are a lack of communication and coordination, latent organizational failures, poor safety culture and blame-oriented processes, inadequate safety indicators and medication errors. This list of problems is consistent with the findings in the earlier, oft-cited Institute of Medicine report To Err Is Human (1999), calling for attention on the vast amount of medical errors committed by US health professionals that could have been prevented. The significance of “human error” as a major cause of unsafe healthcare has garnered considerable interest (Armitage, 2009), however authors such as Reason (2004) argue that the traditional belief that some individuals are error-prone should be revised, instead focusing on error-prone situations and organizational accidents. In Sweden, the National Board of Health and Welfare (Socialstyrelsen) expresses a view similar to Reason’s, stating that mistakes are often the consequences of organizational factors such as inadequate routines, work environment and staffing (2009). Since the beginning of 2011, an earlier judicial system where healthcare professionals involved in medical errors would risk admonitions has been replaced by the new Swedish Patient Safety Act (2010:659), which allows a greater focus on systemic accident analysis.

The research perspectives outlined in sections 2.1-2.3 each provide a quite different outlook on the issue of medical errors, which becomes clear when reviewing recent studies from each perspective on safety in the healthcare domain. Xiao (2005) noted that Distributed Cognition can explain the importance of the physical aspect of the healthcare environment – physical artifacts support so-called “tailoring”, simple modifications serving as local adaptations, and the physical workspace is typically tight, allowing high degrees of implicit communication between team members. Failing to address these aspects when introducing new information technology in the healthcare domain will lead to poorly integrated information systems, which might result in dangerous situations. Focusing on finding explanations to medical errors, Cohen et al. (2006) made use of the DC framework in an ethnographic study of a psychiatric emergency department, which enabled identification of inherent flaws in the distribution of cognitive work. Examples of such flaws included information loss at handovers, non-systematic communication with other departments and use of abbreviations without any consensual meaning across all staff members.

Whereas Distributed Cognition analyses focuses on the details of the healthcare work environment, Resilience Engineering sheds light on a broader issue; Woods (2006) notes that the six goals for healthcare listed in the 2001 Institute of Medicine report mentioned above (Safe, Timely, Effective, Efficient, Equitable and Patient-centered) are actually interacting and to some
extent conflicting. This, the author suggests, means that there is no silver bullet solution leading to the achievement of all goals, but rather that solutions should try to balance the goals and find workable tradeoffs between them. Furthermore, the proponents of Cognitive Systems Engineering and Resilience Engineering take a stance against the prevailing trend of likening good patient safety with no medical errors: Hollnagel (2004) argues that attempts at eliminating accidents in a system will also reduce the flexibility of that system, which is necessary in order to prevent future accidents. The author strongly opposes the notion of “human error”, noting that any complex incident can be dismissed as the mistake of a flawed individual, which inevitably opens up for biased accident investigations and a blame-oriented safety culture. In the CSE approach, studies focus instead on how requisite variety provides the means to control situations, exemplified in the healthcare domain by the analysis of surgical systems by Benn et al. (2008). Inspired by the Extended Control Model, a surgical system is here described as having two levels of control-loops or modes: One is in real-time and provides feedback from surgeries to the second, long-term level, where issues such as redesigning procedures and developing guidelines are addressed, which in turn becomes feedforward to the real-time control-loop.

Moving from an individual perspective to a systemic perspective in the healthcare domain itself might be difficult, however: Amalberti et al. (2005) argue that a major obstacle to developing better patient safety is the current professional autonomy of healthcare professionals, viewing themselves as craftsmen instead of equivalent actors working together in a team. Transitioning to a systemic view will “require health care to abandon traditions and autonomy that some professionals erroneously believe are necessary to make their work effective, profitable, and pleasant.” (p. 756) Moreover, Reason (2004) notes that healthcare is “a very personal business” (p. ii28), where the actions of individuals have a great impact on a situation compared to other safety-critical domains such as the nuclear industry or modern aviation.

3.3 Finding a healthcare case

After establishing that safety certainly is a crucial issue in the healthcare domain, the next objective was to find a suitable healthcare case to study. Once again, one of the principles of Resilience Engineering guided the criterions in this process, namely that one must understand not only what goes wrong, but also what goes right, in order to understand safety (Hollnagel, 2010a). In fact, since failures are rare exceptions to normal functioning, it makes sense to focus on studying normal functioning to best understand how an organization creates the potential for resilience. This means that a valuable insight should be given by studying a case of a healthcare department where the demands put on the department are challenging, but where the process of developing patient safety is still seemingly going well.

With this in mind, I contacted the Patient Safety Unit of Linköping University Hospital, the unit responsible of investigating patient safety development at other departments, and asked for a recommendation of a suitable department to fit this criterion. The recommendation I was given was to seek contact with the so-called Children’s Hospital, a collection of departments with different specialties capable of giving all kinds of care service exclusively to children ranging from newborns up to teens aged 18. Paradoxically, the Children’s Hospital was recommended because of their relatively high levels of incident and risk reporting. This, however, is in line with the thinking at the Patient Safety Unit at the hospital: that reported incidents are only the tip of the iceberg, and that frequent reporting, especially risk reporting, is indicative of a proactive, risk-aware safety culture. This thinking is seemingly in line with the spirit of Resilience Engineering.
and in agreement with that thinking, I asked the Children’s Hospital for permission to conduct my case study at one of their more safety-critical departments – this way, I was allowed to do the study at the Pediatric Emergency Department.

3.4 Research methods
The fieldwork at the Pediatric Emergency Department (PED) was conducted in the period between March 7 and April 3, 2011. All staff members working at the department were informed of the study beforehand through its supervisor, who also informed them that all personal data would remain confidential. In total, I observed the work at the PED during 14 shifts, whereof 10 were day shifts, 2 were evening shifts and 2 were night shifts. Out of each type of shift, one was during a weekend, meaning that I had the opportunity to observe as many different shifts and staff members as possible in order to observe the complete activity cycle at the department. In addition to this, after observing 5 shifts up until March 14 I also had the opportunity to observe a one day simulation training course in emergency healthcare for new staff members, described closer in the subsequent chapters.

During the shifts, I was a partially participant observer, in accordance with the ethnographical principle of being part of the community (Agar, 2008). I wore a medical uniform identical to the ones used by staff members, and regularly attended rounds, handovers and all other types of staff meetings. Due to practical reasons, however, I only had the opportunity to participate in simpler tasks assisting the clinical staff when providing treatment to patients. When appropriate, I asked staff members to explain certain aspects of the workplace or to clarify some part of the activity concurrently being undertaken. These questions served as very short in situ open-ended interviews in the sense of Yin (2003), where informants’ answers are used as the basis for further inquiry.

Two full-fledged focused interviews were also conducted, following the definition of Yin (2003) as about one hour long sessions where a certain protocol of questions is loosely followed to achieve a somewhat more structured form. These interviews were conducted with the supervisor of the department and with the patient safety developer of the Children’s Hospital, responsible for ensuring that incident reports and analyses are conducted and that the recommendations from analyses are implemented. The main reason for inquiring these people in longer interviews is that they both are involved in different parts of the long-term activities taking place at the department, which could not be fully assessed in the time-scale of the observations.

3.5 Data collection and analysis
All data from observations and open-ended interviews were collected by writing fieldnotes in a small notebook that I kept with me at all times at the PED. Data from focused interviews were written directly into a word processor. Furthermore, I had access to a comprehensive amount of documentation from the department regarding rules and routine descriptions, and also got permission to take photos of various artifacts using a digital camera.

Following the principles of Grounded Theory (Strauss & Corbin, 1990), observations were interspersed with coding fieldnotes and data gathered from documentation into open categories, to which new data were regularly compared. Whereas a strict Grounded Theory approach would require initial observations to be entirely unguided by any theoretical perspective, however, the purpose of this case study demanded that some consideration was taken as to the data that would be needed in order to analyze the department using the three theoretical perspectives described in
sections 2.1-2.3. Despite this, the categories emerging during the period of observations were deliberately made independent of any theoretical terminology.

Not until after the completion of all observations, a second period of data processing was begun, this time coding the categories into concepts of the three theoretical approaches, respectively. The Three-Level Analytical Framework (see section 2.1.4) was adopted for the Distributed Cognition analysis, whereas the Extended Control Model (ECOM) (described in section 2.2.4) was used for the Cognitive System Engineering analysis. In context of the latter approach, other similar analysis methods have been proposed, most notably the Functional Resonance Analysis Method (FRAM), also devised by Hollnagel (2004). This method differs from ECOM in that it produces more detailed graphical models of interdependencies in a system, describing all different functions of a system rather than a set of control levels. However, this richness in details easily leads to needlessly complex graphical illustrations that are hard to comprehend, which is why the method was rejected in favor of the ECOM. The Distributed Cognition and Cognitive Systems Engineering analyses were extracted from the same set of categories, conducted in that order albeit partly overlapping. It should be noted that none of these research approaches provide any clear-cut definitions as to which aspects of the object of study that should be included in the analysis – for the sake of being able to compare the empirical findings from the different approaches, the DC and CSE analyses followed the Three-Level Analytical Framework and ECOM as strictly as possible. This meant that any details not precisely fitting the analysis model were excluded, resulting in the analyses almost becoming “parodies” of the respective research approaches. This by-the-book analysis method also served the purpose of minimizing the effect on the results stemming from the fact that a single researcher conducted the case study as well as performed all of the analyses.

In the process of performing the DC and CSE analyses, all information revealing the identities of staff members was removed out of ethical consideration. Furthermore, information on staff member as well as patient identities visible on any images was obscured. Finally, the Resilience Engineering analysis was conducted based on both of the two previous analyses, but also to some degree on data from the original set of categories that had been excluded. Based on these sources of data, the analysis described the department’s capacity of responding, monitoring, anticipating and learning, respectively. In the following chapters, each of the three final analyses is presented one by one. Chapter 4, *The Pediatric Emergency Department*, is meant to correspond to the functional level of the Three-Level Analytical Framework, but is also supposed to serve as an introductory description of the department for the ECOM and the RE analysis.
4 The Pediatric Emergency Department

During 2009, the Linköping University Hospital went about a major renovation with the intent of creating the Children’s Hospital, colloquially known as “the small hospital within the hospital”. The current Pediatric Emergency Department (PED) came about in this renovation, which also saw the formation of the current pediatric surgery unit along the same corridor as well as a pediatric unit for oncology, diabetes and neurosurgery. The new PED has two separate parts: the Emergency Room (ER) and the Child Acute Assessment Unit (CAAU), manned by the same staff.

Two permanent pediatricians work at the PED, but many doctors-in-training at various points of their education work at the department part time. The nursing staff consists of about 30 registered nurses and about 15 nursing assistants, many of them with a specialized education in pediatric healthcare. The PED is managed by a supervisor originally working at the department as a registered nurse.

Being an emergency department, patients commonly arrive with short notice and hardly any time for the staff to make any preparations. The majority of the patients are sent home after a quick examination, but those deemed to require further treatment are transferred to the CAAU. Most inpatients are discharged after no more than up to two days, however, and long-term care planning is not very common since the states of patients change quickly. This creates a need for more frequent monitoring of patients than at many other departments, reflected in the physicians’ routine of making two rounds every day on top of frequent additional controls between rounds.

As mentioned in the previous chapter, my visit to the PED took place during March, which is known at the department as one of the most hectic periods of the year. This is mainly contributed to the periodical surge of respiratory syncytial virus (RSV) infections, known to mainly affect small children. This leads to a period of especially high patient load.

4.1 Workplace description

The PED is built around a single long corridor, with a door separating the ER from the CAAU (see Figure 4.1). The department has a total bed capacity of 13, divided on 12 patient rooms, of which 4 belong to the ER and 8 belong to the CAAU, including one two-bed room. The department has two entrances; one entrance to the CAAU through a side corridor leading from the main entrance of the Children’s Hospital, the other entrance to the ER via elevators in the far end of the main corridor. Acutely ill patients arrive through this entrance, some of which has previously been sent to the main Emergency Department by ambulance. Next to the elevators are separate offices for the nursing staff and physicians at the ER. At two places in the corridor, alarm signs have been mounted in the ceiling, making a buzzing sound every time a patient requires attention as well as indicating the patient’s room number. This leads to a constant beeping at the workplace.
Figure 4.1. The Pediatric Emergency Department.

On the opposite side of the patient rooms at the CAAU is a preparation room for drugs and medication, a room containing other supplies and a room for dishing used equipment. The department has no mutual office for nursing staff and physicians, which is common at other units but known to create a very crowded and noisy environment. Instead, the nursing staff uses two smaller rooms named “modules” for their day-to-day work at the CAAU, while physicians sit in the rounding room. The CAAU is also where the staff has their dining room as well as a coordination office. In the latter is a “patient chart”, a whiteboard where the name of each inpatient is written next to the room number where the patient is staying (see Figure 5.2). Names of the nursing staff and physicians currently responsible for the care of the patient can also be written on the chart. Finally, there is also a resuscitation area for dealing with life threatening illnesses and injuries.

All offices, modules as well as the rounding room are equipped with PCs. Calculators as well as various stationery such as post-its are also provided in these rooms. Outside the resuscitation area is an emergency cart, containing the tools and drugs necessary to treat a person in cardiac arrest. The nurses’ office at the ER and the modules are equipped with similar carts, where simpler medical instruments and some less potent drugs are contained.

4.2 Work procedures

The PED staff gives care service around the clock, involving both medical examinations of new patients at the ER as well as the treatment of inpatients at the CAAU. The following Figure 4.2 illustrates the approximate times for important events:
4.2.1 Nursing staff

The nursing staff work routines follow the three-shift system common in healthcare, with
handovers at the end and beginning of each shift. Handovers usually take place at the nurses’
office as well as in the respective modules at the CAAU. Handovers usually consist of a verbal
meeting, however evening handovers at the CAAU only involves the new shift teams reading
about the patients in the Electronic Medical Record (MR). Handovers at the CAAU are generally
much longer, as they involve inpatients with relatively more complex treatment plans. Nursing
staff members at the ER usually only have very limited information about the patients, such as
the reason behind contacting the department and any treatment performed during the last shift.

Nursing staff members usually work in “care teams” of one registered nurse and one nursing
assistant. During day and evening shifts, the ER is staffed by one care team in the nurses’ office,
and the CAAU is staffed by two care teams working from their own respective module with
treatment of the inpatients. During night shifts and over weekends, there is only a single nurse at
the ER. The staff at the CAAU is reduced to one care team during night shifts, sometimes
choosing to work from the dining room instead of one of the modules.

The common work tasks for nursing teams involves regular checking of patients’ vital parameters.
This often means using various technical equipment, such as pulse oximeters for measuring
patients’ oxygen saturation. The registered nurses are also responsible for administering
medication, while nursing assistants usually take care of providing patients with food, drinks and
nutriment in the case of infants. Patients (or their parents) might also call for attention by
pressing the alarm button of the room, which activates the alarm signs in the corridor indicating
room number as well as produces a buzzing sound. This happens frequently, and prompts the
responsible care team to go to the room and assist. Patient rooms 101 and 102 at the CAAU are
also equipped with a patient monitor that can be used for continuous monitoring of the patient’s
state, triggering the alarm if any measured parameter goes outside a preset boundary. There is also
an emergency alarm with a more frequent sound, only activated in an emergency situation when
additional resources are immediately needed and always activated by someone in the staff,
presently attending a patient.
All treatment episodes must be documented by the nursing staff in the patient’s medical record. At the CAAU, the Electronic MR system is accessed through the PC in the module, where everything that is written is instantly uploaded in a common database and readily accessible to other members of the staff. If every single treatment was to be written as a separate note, however, the Electronic MR would soon be cluttered, making it hard to find relevant pieces of information. Instead, nursing staff members make use of so-called “report papers”, where temporary notes regarding all patients currently treated by the care team is written. Furthermore, the care team uses a “patient binder” for each patient, serving as an intermediate tool between Electronic MR and report paper. These binders contain different lists for different types of information, updated after each treatment. At regular intervals, the complete data of the lists in the patient binder is summarized by the nursing staff and written as a single entry into the Electronic MR. Data is sorted into separate categories, facilitating future investigation in certain aspects of a patient’s health condition. In order to do this, however, the user of the Electronic MR has to scroll through a long list with several categories in order to find the right one. One nurse points out that this laborious process often is omitted at other departments, where all entries simply are placed under the all-encompassing “other” category, rendering the database function of the MR useless. As it seems, however, the staff members at the PED do take the time to write notes where they belong. Finally, all entries written into the Electronic MR should also be signed in order to be valid.

Nursing staff members at the ER might occasionally use the Electronic MR before a patient arrives, in order to gather information about any previous care episodes that might be of importance. The treatment of these patients at the department, however, is of such short duration that no electronic documentation is needed. Instead, a paper-based Emergency MR is used, which is tightly linked to the process of triaging, expanded upon in section 4.2.4. Instead of the list of all patients included in the Electronic MR and used at the CAAU, nursing staff members at the ER write down the names and times of arrival of all patients in a paper-based “patient list”, put in a binder stored in the nurses’ office.

4.2.2 Physicians

The physicians at the PED begin their day at 8 am with a morning meeting together with physicians from the other departments of the Children’s Hospital. The staff from each department quickly reports any news from the night and briefs the others about any patients that might come to require particular attention during the day. At 8.30 am, the physicians are supposed to be at the PED. Over weekends, there will be only one physician, who heads to the ER to work in the physicians’ office during the day. On workdays, there is also at least one pediatrician in charge of the CAAU during the day, sitting in the rounding room and reading the latest entries in the Electronic MR to check the latest updates on the inpatients.

At ca 9 am and 3.30 pm, respectively, the morning and afternoon rounds takes place in the rounding room at the CAAU. The two nursing care teams attend the round successively, discussing the states of their respective patients together with the pediatrician and any doctors-in-training. The nursing care team provides an update on the latest changes of vital parameters as well as additional information regarding overall patient condition. The pediatrician in charge might prescribe new medication, adjust, or extend previously given prescriptions. Over weekends, rounding is led by the physician at the ER since no pediatrician is working at the CAAU.
The afternoon round normally ends after all patients have been discussed based on the Electronic MR, after which the pediatrician hands over the responsibility for the CAU to the physician at the ER with a very short verbal report at the physicians’ office. Morning rounds, however, are finished with the physicians and nursing staff visiting all patients, either after the report from each care team or after both care teams have given their respective reports. Each patient is quickly examined and afterwards, additional adjustments to prescriptions might be made by the pediatrician. After the round is completed, physicians return to the rounding room to write prescriptions into the Electronic MR system. Their day-to-day work tasks then consist mainly of administrative work, telephone consulting, dictating, as well as receiving patients with appointments at the main Children’s Hospital office. Every now and then, they might also do adjustments to prescriptions based on new reports from the nursing care teams, or make a decision to discharge a patient.

4.2.3 Coordinator
In connection with the creation of the Children’s Hospital, a new work role known as “coordinator” was introduced. At the PED, this role is usually occupied by an experienced nursing assistant, who does long-term scheduling duty, answers phone calls, reports malfunctioning equipment and takes care of referrals sent to the wrong department. The coordinator also communicates with all the care teams and keeps track of the overall patient load at the PED during the day, calling upon extra staff if the situation demands it.

4.2.4 At the ER: metts-p triage
Nursing staff and physicians at the ER are constantly ready to receive new patients arriving at the PED by foot or by ambulance. Many visits are agreed in advanced by phone, although some patients arrive completely unexpected. The primary task of the nursing staff is to do the systematic prioritization of patients called “triage”. The triage system used in most Swedish hospitals is called the Medical Emergency Triage and Treatment System, METTS. The staff at the PED uses a newer version named metts-p, intended specifically for pediatric care. The process of using metts-p begins with assessing a number of vital health parameters regarding the state of the patient’s ABCDE: “Airway”, “Breathing”, “Circulation”, “Disability” (alertness) and “Exposure” (body temperature). This mnemonic is built-in to metts-p and serves as a reminder of the priorities of treatment in an emergency situation, since each of these are vital to life and are required to be treated, in that order, for treatment of the next to be effective. Depending on the age of the patient, one out of seven parameter tables is then selected, providing different value ranges for each parameter and four corresponding levels of priority, represented by colors: red (highest), orange, yellow and green (lowest). The appropriate color for each parameter is checked in a predefined box on the Emergency MR. Based on the patient’s reason for contacting the PED, a suitable “ESS code” (Emergency Symptoms and Signs) is then selected. Each ESS poses a number of criterions regarding the patient’s symptoms and provides the same priority colors, of which the one corresponding the best is checked on the Emergency MR.

Based on the colors chosen for all vital parameters as well as ESS, a suitable overall priority level is selected for the patient and checked on the Emergency MR. This final color corresponds to a specific time limit before the patient must be examined by a physician and also provides instructions regarding how frequently the patient must be tended to by a nurse and what lab tests should be taken. Red color indicates a possible life threat and requires immediate medical examination as well as a nurse standing bedside until priority can be changed to the orange...
priority level or lower. There is also an additional color, blue, that can be checked on the Emergency MR for patients that do not require any acute care or triage and can be tended to if necessary. Lowering a priority after the initial triage must be approved by a physician.

At the PED, each nurse carries copies of the seven parameter tables with them, while the ESS codes are put in yellow binders that can be found in the nurses’ office, the resuscitation area, each patient room as well as one for the whole CAAU. After triage is finished, the Emergency MR is placed in a wall mounted plastic container in the physicians’ office, and a plastic clip of matching color is in turn attached to the container. Each container is marked with a patient room number or simply “waiting room”. This way, the physician at the ER is quickly provided with clearly visible information regarding the priority levels of each patient as well as the room where the patient is or whether the patient is still in the waiting room.

Figure 4.3. A plastic clip indicating triage color.

4.2.5 At the CAAU: Treatment and drug administering
While the main task at the ER is to assess patients’ health states through triaging, the central activity at the CAAU is the treatment of inpatients, including drug administering. Administering drugs to child patients is a sensitive matter: Drug dosages are normally represented as mg of medication per kg of body weight, and since the PED treats all children from newborn infants up to 18 year old teens, patients’ weights can vary between 300 g up to 100 kg. This leads to a very high variability regarding what drug dosage could be reasonable in a given case, and in the case of small children, even a small difference in administered dosage could have severe consequences. Furthermore, many drugs are dispensed at a predetermined concentration or need to be diluted, meaning that drug strength is re-represented as mg/ml and the dosage to be given in ml. All of these representations must be correct, all the way from the physician writing the prescription to the nurse reading it and preparing the drug, for the correct dosage to be administered. The Electronic MR has no built-in alert function for warning against overdosing.
5 Distributed Cognition analysis
The Three-Level Analytical Framework (see section 2.1.4) was used when analyzing the PED as a distributed cognitive system. The first and foremost step of this analysis is to identify the overall goal of the system. The goal of the PED might seem obvious (i.e. “to treat all patients”), but in the case of acute healthcare, things are not quite as simple: In many cases, the department actually serves as a temporary care unit which will only provide treatment in order to stabilize acute health conditions, thereafter transferring patients to other departments where specialized care can be given. Therefore, the goal is rather “to ensure that the proper treatment is given to all patients”. However, the PED also has the explicit aim of trying to reduce the number of patients who are actually not in need of acute care, but should rather seek contact with a health center. Therefore, the complete goal formulation of the PED should be “to ensure that the proper treatment is given to all patients in need of acute care”.

The first level of the Three-Level Analytical Framework, the functional system, consists of a description of the overall goal and behavior of the system, including historical accounts. Together with the goal identification above, chapter 4, The Pediatric Emergency Department, is meant to correspond to this level and it will therefore be left out of this chapter. The following sections attempt to explain how this goal is achieved by analyzing the remaining two levels of the framework.

5.1 The representational level
The second level of the framework deals with representations, and how they are created, transformed and propagated across the different constituents of the system, people as well as tools. In order to properly describe the distributed nature of these transformations and propagations, it also becomes relevant to analyze cooperation between system constituents and how it is achieved through socially structured communication.

5.1.1 The chain of representations at the PED
Since the overall goal of the PED is “to ensure that the proper treatment is given to all patients in need of acute care”, the patients should reasonably be the natural starting point when analyzing the chain of representations. New patients and their health conditions are the input to the system on which it operates. The moment a new patient seeks contact with the PED, either by calling beforehand or by simply showing up, the nursing staff at the ER will make a note in the paper-based “patient list” regarding name, ID, reason for contact and time of arrival. This list serves as a collected representation of all patients currently staying at the ER, quickly providing an overview of the current situation. When a patient arrives, the number of the room where the patient is placed is also noted, and a check mark might be written at the end of the row in the list. After discharging a patient, the row is crossed over with a mark pen as seen in Figure 5.1.
Although the patient list provides an overview of the situation at the ER, the health state of each patient is only represented by the single line regarding the reason for contacting the PED. By the process of triaging, another more elaborate form of representation of the health state is created. The first step is to represent the health of the patient with the values of the five vital parameters. Next, these values are transformed into colors using the parameter tables as discussed in section 4.2.4. After transforming each vital parameter into a color representation, the reason for contact is represented by a corresponding ESS code, which in turn is also represented by a color, finally leading to the overall patient state to be represented by a certain color which in turn represents a priority.

This process from patient health to parameter values to colors to a priority is exclusively a bottom-up process, moving from the real world to a successively more abstract representation. It should be noted, however, that there are actually several top-down processes happening simultaneously. First of all, nursing staff will have two sources of representing the patient’s state before assessing it physically: any previous notes that might be looked up beforehand in the Electronic MR, and the patient’s reason for contact in the first place. These representations guide the triaging, especially the choice of a suitable ESS code, which in turn is one of several pre-defined categories of typical symptoms that patients are expected to have. Secondly, the vital parameters themselves can be considered as pre-defined representations of the ABCDE mnemonic: oxygen saturation represents “Breathing”, pulse represents “Circulation” et cetera. In fact, even the letters ABCDE serve as a pre-defined way of representing the most vital aspects of the patient’s health in the first place. Furthermore, from the physicians’ point of view the triage process is entirely top-down: The first input will be the color representation of priority, which together with the reason for contact constitutes the representation of the patient’s state before the patient is actually assessed. The bottom-up process leading up to the color representation is entirely secluded.
Patients that are transferred to the CAAU will no longer be referred to as having a certain color of priority. They are added to the list of patients in the Electronic MR as well as the patient chart at the coordination office, both tools substituting the patient list binder in the nurses’ office as a way of representing the overall situation.

![Image](image.png)

**Figure 5.2. The CAAU patient chart.**

If the physician determines that some kind of medication should be administered to the patient, another sequence of representational propagations is initiated. Administering medication is represented by the physician in the form of a prescription, specifying dosage form, type of drug, drug strength, dosage and route of administration, either hand-written on the Emergency MR in the case of the ER or added to the Electronic MR using a pre-defined template in the case of the CAAU. Nurses decode this representation into specific work tasks, often filling in missing information themselves, such as route of administration, which is often implied. Electronic prescriptions are hand-copied to individual “report papers” (see section 4.2.1) as a form of intermediate representation. After administering drugs and providing other treatment, nursing staff builds up a new representation hierarchy by check marking any notes they have made on their report papers, then either signing the treatment directly on the Emergency MR or writing new notes in “patient binders” (see section 4.2.1) in the case of the CAAU. Here, the patient binders serve as a buffer providing loose coupling to the system, allowing pieces of information to be collected over the course of a shift before they are transferred to the Electronic MR in more easily manageable summaries.

The treatment process leads to patients getting better and eventually to their being discharged from the PED, creating output from the cognitive system. Other patients will have been transferred to other departments directly after assessment resulted in the judgment that other competencies were needed.

### 5.1.2 Coordinating the flow of representations

While the transformation between different representations of patient state can be depicted as a long sequence from input to output as demonstrated in the section above, many activities at the PED are typically performed in parallel and thus there is a need to coordinate them. From a DC
perspective, the means of coordination are the constraints of the behavior of the staff members. At the PED, these constraints mainly come from rules and tools that guide actions into sequences. However, there are very few examples of actions actually being physically disabled by the structure of the cognitive system – most constraints are purely symbolic in nature, with the exception of physical access to the medication room being permitted only to registered nurses through the use of keycards. The symbolic property of most constraints provides the cognitive system with a very high degree of flexibility, opening the possibility to suppress the disabling of actions when a situation demands it.

Choosing between the four possible priority colors when triaging, for instance, is not always a straightforward task. Descriptions of symptoms for the ESS codes do not always match the reported symptoms of a patient perfectly, and depending on which code that is chosen, the resulting priority level might turn out differently. The solution to this problem is for nursing staff to always overtriage in uncertain cases, for instance choosing orange priority although the ESS would make priority green. Although the initial color is determined by the nursing staff, physicians are the only members of the staff that are allowed to lower a patient’s priority level once set. Nurses work around this by verbally informing about overtriage to physicians, who either assess those patients directly in order to lower their priority or wait longer before assessing them. In stressful situations, nurses might simply lower the priority themselves and inform physicians verbally about it.

Suppressing disabling actions is not only possible because constraints are purely symbolic, but written procedures on triaging at the PED also endorse some liberty and use of “common sense” regarding the color categories, recommending staff to communicate and agree upon any deviations from the instructions for the priority colors if deemed appropriate. Use of experience and knowledge are also deemed as important, for instance to skip the time-demanding process of triage when it is obvious that a patient has a high priority. The staff seems to comply with these recommendations, as seen by the example in Figure 5.3 where a patient’s oxygen saturation (SpO2) was found to be critically low, leading the staff member to omit the remaining steps of triage and directly select a red priority color, marking it extra clearly by drawing circles around the relevant check boxes.
In a rapidly changing environment like an emergency department, the ability to skip restrictions might be crucial. As stated by one nurse, the general principle is that “you do what you have to do to save lives”.

5.1.3 Tools for coordination

Even though constraints given by the system might have to be bypassed at critical moments, they normally facilitate coordination during work tasks. The patient chart at the CAAU as seen in Figure 5.2 does not only serve as a summarized representation of all patients by listing their names, but is also a coordination tool since it lists the names of staff members as well. Nursing staff will normally take a look at the schedule for the next shift prior to their arrival, checking who will work at the ER and the modules at the CAAU, respectively, and updating the patient chart with the new nursing staff members’ names. As the new shift begins, the nursing staff members assemble in the coordination office and assess the chart, determining which patients should be treated by which care team. If some of the patients are judged to demand more effort than the others, they might be assigned to the care team of one module while the other team takes care of the larger group of less demanding patients.

After staff members have assessed the patient chart and moved to their respective work locations, activities are coordinated through the use of quite different tools. At the ER, the system of placing each Emergency MR in a container at the wall of the physicians’ office after triage serves as a coordination tool functioning similar to the patient chart. The wall guides the activities of physicians by visualizing the current priorities and informing them regarding the patient rooms
where patients have been placed. Furthermore, the “tailoring” discussed in section 3.2 is present with the wall, with the plastic clips attached to the containers, colored correspondingly to the priority colors of metts-p. One physician remarks that the clips “attract the attention of the eyes”, enhancing the color representations and quickening decisions. After medical examination of a patient is finished and further treatment has been determined, physicians update the Emergency MR with instructions and place it in a special hatch, built into the wall between the physicians’ and nurses’ office at the ER, as seen in Figure 5.4 below:

Figure 5.4. A tailored hatch at the ER.

This is another example of how tailoring has been used at the ER to create a coordination tool. Here, the activity of the nursing staff is guided by the hatch, providing visual cues indicating that some action should be performed.

At the CAAU, the Electronic MR is the primary tool for coordinating activities between physicians and nursing staff care teams, ensured by collecting all information regarding one patient at the same spot and making it readily accessible to all staff members. Every time the nursing staff writes a note, it will be uploaded to the database and marked with a time stamp, making it possible to follow the sequence of care acts chronologically and look back at the patient’s previous healthcare contacts. The prescription module of the Electronic MR also provides support for coordination by including a timeline, indicating the time for each administering of a drug. Even the nursing staff and physicians working at the ER make use of the Electronic MR system to some extent, sometimes reading a patient’s medical history. All paper-based Emergency MRs are also eventually scanned and added to the electronic counterpart.
Although the Electronic MR is the only “valid” information source, the report papers used by nursing staff at the CAAU are another useful tool for coordinating more frequent activities. Typically, a care team will begin their shift with both persons noting all tasks on their respective report paper during the handover. Afterwards, the care team members go through the first group of tasks and assign them between each other. The tasks are then executed in parallel by the two care team members, check marking completed tasks continuously. When all tasks have been completed, the team members reassemble in the module, sometimes updating the patient binder with the latest parameter readings, and repeat the process for the next group of tasks.

5.1.4 Tangibility and coordination

Although actions are typically not physically disabled at the PED, the physical aspect is actually what constitutes the major difference between the primary tools for coordination used at the CAAU and the ER. The fact that an Emergency MR is something paper-based, tangible is what enables it to be placed in a container at the wall of the physicians’ office, and this property also provides the opportunity for tailoring such as the paper clip system. Furthermore, the reason why the wall itself functions as a coordination tool is the very spatial proximity between the MRs, making it possible to quickly assess the overall situation at the ER and choose the next action to be performed. In contrast, the intangible Electronic MR coordinates activity at the CAAU by precisely the opposite principle – instead of collecting information at one spot, it is spread out and accessible from PCs located anywhere on the department.

This difference is furthermore reflected in the actual physical structure of the workplace: At the CAAU, the modules and the rounding room from where nursing staff and physicians work are distributed over a relatively long section of the corridor as seen in Figure 4.1. Using a paper-based medical record system here would be impractical, forcing staff members to constantly move back and forth between the rooms whenever a record is to be updated. Indeed, this was also the case at the time before the Electronic MR system was introduced at the department, during which paper-based MRs were kept in a centralized archive. I am told by the staff that this led to constant problems with missing records and lots of extra work. The architecture of the present ER, however, allows for a paper-based system to work: Physicians’ and nurses’ offices are placed next to each other, with the hatch in the wall further facilitating information transfer. Although the system of containers holding Emergency MRs could in principle be substituted by a computerized tool, such a system would have to retain the openness and physical proximity of the current system in order to be efficient, and there is a risk that ad hoc tailoring would be prohibited, reducing flexibility. The advantage of the structure of the ER can be understood by examining the nature of the work tasks: New patients arrive unexpectedly, leading to constant changes of the current workload. In such an environment, coordination tools enabling quick situation assessments and rich face-to-face verbal communication between physicians and nursing staff are crucial means for fast information updates. At the CAAU, the time horizon is relatively longer and even though verbal communication between physicians and nursing staff is common during the course of shifts, the rounding will be sufficient to lay out overall plans for the distributed work tasks.

5.1.5 Communication

As seen in the description of how work at the PED is coordinated, it is tightly linked to verbal communication – indeed, both verbal and written communication are integral parts of the work tasks at the department as necessary means for successful coordination. All through the activities
taking place at the PED, written information is accompanied and completed by rich face-to-face verbal communication. There seems to be an implicit social rule stating that a staff member is expected to verbally inform the others before leaving the office or module, something that becomes clear whenever someone has been away for a longer time period and apologizes upon returning. As mentioned in the previous section, face-to-face verbal communication is in general used less at the CAAU than at the ER to coordinate activity between nursing staff and physicians, but within the nursing staff care teams themselves, verbal communication is used throughout a shift to regularly check the task-performing progress of the other team member. This is indeed necessary, seeing how both members of the team have all tasks noted on their report papers, but only mark the ones they complete themselves – without the verbal checks, some care act could easily be executed twice by accident. At the ER, all staff members, including both nursing staff and physicians, constantly confirm performed treatments verbally and will also frequently discuss rare cases where a triage color is hard to determine, for instance. Typically, verbal information will be used to complete fragmentary written information. As mentioned before, prescriptions are not always explicit and nurses will often ask physicians for more specific information. Furthermore, both written and verbal information is at times accompanied by body gestures: During a handover, one nurse was describing the state of a patient with two catheters, pointing to her own right arm and stating “This one has been there the longest”. The nursing assistant of the new care team made the note “2 catheters (right arm longest time)”, thereby transforming the combined verbal and embodied representation of the catheter to an entirely new, written representation. Other information might simply be easier to describe with body language than with words, such as imitating a patient’s way of breathing. In this case, the original representation of the patient state is unaltered and shared without any use of tools for writing information.

5.1.6 Work roles and communication

Although communication at the PED is truly multimodal, there are distinct differences between physicians and nursing staff. In general, physicians at the PED seem to make very little use of temporary written notes, instead relying on the summaries provided by the Electronic MR. During the morning meetings with physicians from all departments of the Children’s Hospital, information exchange is entirely verbal with the exception of a few physicians taking notes. Furthermore, much information supposed to be written by physicians is frequently left out completely. At the patient chart, the field “DR” was mostly blank during my visit at the PED, whereas the fields for nursing staff were updated prior to every shift. Similarly, the field “Dr In” on the Emergency MR, supposed to be filled in with a time indicator after the physician at the ER has assessed a patient for the first time, was blank on nearly all instances of Emergency MRs I reviewed during my observations. Since this information is so seldom explicitly written, it is apparently either not important or entirely substituted by verbal communication. On one occasion, a nursing assistant went to the physicians’ office to ask the physician at the ER whether he had assessed a patient or not. However, the physician was talking on the phone, and consequently the nursing assistant changed strategy and checked the patient’s Emergency MR to see if the “Dr In” box was filled – as usual, it was not, and realizing that the empty field could actually mean anything, she waited for the phone call to end and then asked the physician.

One physician suggests that writing notes is only necessary for less experienced physicians, implying that notes serve as a memory aid that one can do without as soon as the information is internalized. However, another physician points out that this is made possible only because the nursing staff gives continuous updates on patient states, informing physicians on current states
and providing them with indications regarding what actions to perform. Seen this way, the memory task is not internalized in the minds of physicians so much as distributed across both physicians and nursing staff, with the latter group acting as a human interface to the former to aid coordination. This situation could be seen as a reflection of a possible social structure guiding the division of labor between physicians and nursing staff: nursing staff gathering and providing information on patients through frequent interaction, to be entered into the Electronic MR and integrated by physicians making the decisions regarding future treatment. However, such an interpretation fails to take into account that the nursing staff at the PED frequently takes active part in decision making, giving the medically responsible physician suggestions or requesting the approval of treatments already decided upon. The metaphor of a nursing staff as a human interface to the physicians at the PED must therefore acknowledge that the interaction is never unidirectional, but a mutual exchange of interpretations and evaluations of observed patient states.

5.1.7 The explicitness of communication

Although verbal information might serve as a way to clarify gaps in written information, many times the verbal communication itself leaves many messages implicit. Since all staff members share the same medical knowledge to a great extent, many times the meaning of a certain parameter value will be left out, making it incomprehensible to a layman observer like myself. Conversely, implied messages are also used at the PED for assessing when a situation is not entirely understood, for instance by referring to a patient as “mystical” or “suspicious”. Apart from common medical knowledge, shared knowledge between staff members of the context and history of interactions with patients is frequently used to convey very short yet intelligible messages, such as “…where did you mean?” - “three.” Here, the identity of the patient was substituted entirely by the number of the room where the patient was staying, and nothing was explicitly stated about the nature of the treatment to be performed.

Naturally, implicit messages highly rooted in a certain context will also be more limited. During an especially quiet day shift, the care team working at the ER had only a handful of patients, and because of the low workload, there was no need to keep written record of the rooms where patients were staying or their times of arrival, since both members of the care team could keep this information in their heads. When the shift ended, however, the care team members were suddenly reminded that this information needed to become explicit as the next care team arrived. This case illustrates one situation where the shift from implicitness to explicitness takes place, namely during handovers and other meetings. Especially during rounding, discussions between physicians and nursing staff regarding the patients will be more detailed and precise than during the course of shifts. Explicitness of communication during nurse handovers is more varied, since the new care team might sometimes need a thorough introduction to the state of a patient, and at other times only need a very short confirmation that everything is “as usual”.

5.1.8 Explicitness and written communication

These varying levels of explicitness can be seen not only in the verbal communication, but are also clearly reflected in the nature of information in the written modality. As stated above, the Electronic MR is the top level coordination tool: All other representations of patient states in patient binders and paper-based Emergency MRs are supposed to eventually end up in a computerized form in order to be valid. As a tool for distributing information instantly to all other staff members and even to caregivers outside the department, information must be very precise
and decontextualized: The pre-defined templates used for writing prescriptions, for instance, are highly standardized and automatically include the unit of measurement, even in cases where this information is superfluous. Whereas other written notes are destroyed at the end of a shift or when a patient is discharged, the Electronic MR is intended to serve as a long-lasting documentation on all encounters with the healthcare, further necessitating information to be independent from historical context of interactions.

The next level of written information at the PED is the paper-based Emergency MRs and the patient list used by nursing staff at the ER, as well as the patient chart and patient binders at the CAAU. These tools all have in common that they are used to exchange information between people not sharing a complete contextual knowledge, meaning that a certain degree of standardization is needed, but are still used by a limited group and during limited time spans, allowing for more freedom than with the Electronic MR. This can be seen clearly in the patient binders used by the nursing staff, where the various lists used for documenting measures have predefined table formats, but where the actual notes written are full of abbreviations and frequent omitting of details such as the unit of measurement. For some parameters, values will sometimes be written with an arrow before them pointing upwards or downwards, for instance “↑0,25l”. This way of notation indicates that the previous value at the row has increased with 0,25 l. Such a mix of absolute and relative values could be seen as a “code” used by the nursing staff – not entirely indecipherable to an outsider like myself, but still more difficult to interpret than the precise notes in the Electronic MR.

The final level of written information is the report papers, used at the CAAU by the nursing staff for personal notes. Whereas the information written in patient binders and patient list can be understood by nursing staff through common context or conventions such as the use of certain “codes”, the staff members admit that notes in report papers are truly incomprehensible to anyone but to the person who wrote them. The meaning of notes are highly connected to context, with numerous examples of fragmentary information like stray values, personal use of abbreviations and telephone numbers with no names written. Since the meanings of such notes are highly connected to context, even the person writing them is likely not to understand them after some time, testifying the short life span of the report papers. However, staff members will occasionally save them until their next shift, providing them with some history of interactions with any inpatients that are still hospitalized.

5.2 Implementational level
On the third and final level of the framework, it is time to discuss how the transformations of representations in the PED, through coordination achieved by communication, are realized at the cognitive level as computations distributed over people and tools.

5.2.1 The computational task of the PED
Seen as a computational task, the process of treating a patient at the PED beings with the nursing staff at the ER computing a triage priority color based on a range of parameters, serving as a representation of the patient’s state. A suitable treatment is then computed by the physician at the ER, leading to the patient state changing and new assessments to be made. If the patient is transferred to the CAAU, a slightly more complex assessment routine will take over, including numerous computations on representations of parameter values on different written tools.
Prescriptions also trigger a chain of computations to be made by a registered nurse to deliver the correct dosage.

As described in section 4.2.5, the process of administering a drug is a rather complex series of computations – first, the physician must calculate the proper dosage of medication based on the weight of the patient, either as mg or as ml of medication for drugs that are or should be diluted, and transform this into a written prescription on the medical record. The nurse then decodes the prescription, either assessing it directly from a computer in the medication room or copying it to a report paper, and does the actual preparation of the drug, sometimes including diluting and/or using a syringe to take in liquid dosages. For each of these steps, the primary tool being used both by physician and nurse is a simple pocket calculator. From the nurse’s point of view, the computation of the proper drug dosage is ready-made by the physician, but there is no simple way to check if this computation is correct and no warning system in the Electronic MR for overdosing. Some physicians work around this problem by including both formats of drug dosage in the prescription: If the drug strength is 100 mg/ml and the drug dosage is 2.5 ml, instead of simply writing “2.5 ml”, the drug dosage is written as “2.5 ml = 250 mg”. This way, the drug dosage is represented in a format which includes the history of how it was computed, facilitating error detection. Furthermore, detecting errors when preparing drugs in liquid format might be facilitated by a simple picture on the inside of the door to the medication room, seen in Figure 5.5:

![Figure 5.5. A visual reminder about the risk of overdosing.](image)

Supposed to be noticed on the way out from the medication room, this simple warning includes two syringes of different volume, taped onto the piece of paper next to a picture of a small infant. While the standard, numeric representation of dosage provides no information to an inexperienced person of how big it is, these syringes serve as a purely visual re-representation of dosage to be compared to the volume of the syringe used when preparing the drug, hopefully functioning as a last defense against overdosing.

When treating life threatening conditions, drug administering must be very quick. This is supported by the use of an emergency dosage table on the wall of the resuscitation area, as seen in Figure 5.6:
Here, proper dosages for a number of potent drugs commonly used in emergency situations are given for seven age categories, as well as including referential dosage levels for adults. Below each age category is a weight, roughly known to correspond to children of that age. If weight must be estimated quickly without the table, the rule of thumb used at the PED is that weight = 2 * (age + 4). Using the table, however, this is pre-computed and easily assessed just from looking up age.

After choosing the proper age/weight category, the dosage for each drug is also pre-computed to allow for quick administering. The table will not give as exact dosages as with non-emergency when the exact weight is given, but good enough to work quickly and to prevent an overdose.

5.2.2 Tools shaping cognition

According to the Distributed Cognition perspective, the way we use tools shapes the way we think. At the PED, this is most obvious when the verbal communication between staff members is analyzed, where it becomes apparent that the representations of patients actually become indistinguishable from the patients themselves in the minds of the staff members. At the ER, the colors visualized by plastic clips on the Emergency MRs are not only thought of as arbitrary symbols representing different priorities, but patients are referred to not as having the colors, but as being them – a patient really is orange, and with that property follows certain treatment actions to be performed. When a patient is moved to the CAAU, it is no longer represented by the color, instead being referred to as a mix between first name and patient room number, often switching between both in the same conversation. Furthermore, staff members will communicate about treatment as being given to the medical records and patient binders directly, rather than the patients they represent.
The method of representing patients with priorities existed before metts-p, but instead of four colors, the three grades 1, 2 and 3 were used and there was no systematic way of prioritizing treatment. Instead, staff members had to rely entirely on their experience, something commonly known in the healthcare domain as having a “clinical eye”. Metts-p introduced a whole new way of thinking about priorities, and a new, highly sequential process of assessing them as described in section 4.2.4. In principle, however, many steps could be performed in a different order. By examining the design of the Emergency MR used by the staff at the ER compared to the older version used before the introduction of metts-p, it is revealed how the tool helps to coordinate this sequence:

![Image of Emergency Medical Records]

**Figure 5.7. Two Emergency Medical Records: new (left) and old (right).**

In keeping with the standard Western civilization way of writing, the Emergency MR is supposed to be checked from top to bottom, left to right, and because of this, sequences of actions can be coordinated by placing boxes in a specific order. Reading the new Emergency MR from top to bottom, the first thing that attracts attention is two fields in thick red lining at the very top. These are for checking if the patient has blood contamination or hypersensitivity, two critical conditions that need to be assessed before any contact with the patient is initiated. Directly to the right are fields for putting a sticker on the MR with the name and ID of the patient, as well as a box for checking that ID has been confirmed. The next group of fields is for filling in the reason for contacting the PED as well as any information regarding the state of the patient known before triage.

Up until this moment, the old Emergency MR has followed roughly the same layout, but the introduction of triage on the new MR brings with it some important differences: First of all, vital parameters are filled in before filling in priority, which seems natural since priority is based on the values of these parameters when triaging. The old MR has fields for measuring vital parameters written after the field for priority. It should also be noted that the triage of the new MR begins with checking age of the patient, which is entirely lacking from the old MR since this information was not used when assessing priority (and was available via the national identification number in any case). Secondly, the fields for filling in the priorities on the new MR have a thick lining, colored corresponding to each respective priority color of metts-p. This certainly gives a clear
representation of each color, but it also makes the fields adjacent to them easier to miss. Indeed, according to the nursing staff, the field for filling in weight, right above the orange triage field, is often forgotten when triaging. Fields for checking age category and parameter values should be equally hard to detect, but these are necessary to know in order to proceed with the triage, meaning that they will have to be filled in.

Furthermore, the order of vital parameters on the new Emergency MR follows the ABCDE mnemonic from top to bottom, meaning that the parameters will be checked in order of importance. Depending on chosen age category, the parameter tables provide different pre-computations for the value of the parameter, as seen in Figure 5.8:

![Figure 5.8. Metts-p parameter table.](image)

This step is actually specific for metts-p, the pediatric version of METTS, where small differences in age greatly affects the typical parameter values – the adult counterpart, METTS-A, has the same value ranges correspond to the same color regardless of age. This is evident from the design of the Emergency MR for adults used at the main ER, where the pre-computations are pre-printed in the fields for the various priority colors as seen in Figure 5.9 below:

![Figure 5.9. Adult triage system, METTS-A, on main Emergency Record.](image)

The slight disadvantage of not having the pre-computations directly accessible at the Emergency MR makes the metts-p somewhat more complex in this respect, and furthermore results in the triage process being secluded from the physicians at the ER, as discussed in section 5.1.1.
5.2.3 Tangibility and cognition

In section 5.1.4, I discussed how the tangible aspect of tools at the PED affects the way in which they support coordination of activities, and how the physical environment itself also serves as a tool for coordination. For the individual staff members at the PED, the tangibility of tools can also be an important aspect of cognitive activities. Personal solutions are invented for distributing memory tasks, such as tailoring medical instruments by sticking post-it notes to them as reminders about a certain treatment or other action. This can be seen in Figure 5.10, depicting a case where a nebulizer was marked with a note by a nurse to signify that it should be moved to the main Emergency Department. Another nurse took the opportunity to place an oximeter also to be taken to the main Emergency Department next to the first instrument, utilizing “intelligent use of space” as described by Kirsh (1995).

![Figure 5.10. Intelligent use of space at the ER.](image)

In this example, the deliberate placement of two objects close to each other serves as a visual cue that the message on the post-it note is supposed to be applied to them both. Other objects are deliberately designed to support a certain task at a certain place: It is probably no coincidence that the clocks mounted on the walls of patient rooms all have a hand showing seconds, useful when measuring the breath frequency of a patient or giving a drug inhalation for a limited time, while the clocks at the offices do not, since they are only used for rough time estimates.

Furthermore, I discussed how the patient chart at the CAAU and the Emergency MRs on the wall at the physicians’ office both make use of physical proximity to coordinate activities, but at the implementational level, this also creates a representation of the department’s current workload. The plastic clips attached to the containers serve to refine the workload representation, going from a visualization of the sheer number of patients to include their respective priority level, indicating how demanding they are in terms of treatment. In rare cases, all patient rooms at the ER will be occupied and there will be more patients in the waiting room than there are plastic containers at the wall, meaning that Emergency MRs are stacked on top of each other as shown in Figure 5.11. In this way, the physical limitations of the containers themselves provide a powerful cue that workload is very high.
5.2.4 Workload and explicitness of information

However, a closer examination reveals that the plastic clip system is not really utilized unless workload reaches a certain threshold. When there are only a few patients at the ER, clips often remain on a container long after a patient has left, or might be omitted altogether. Likewise, physicians will prefer to give Emergency MRs with new prescriptions directly to nurses during calmer periods, seldom using the hatch between the physicians’ office and the nurses’ office. When confronted with these observations, staff members admit that the tools are not really used to their full extent when workload is low. Apparently, the staff members’ internal memory of the history of activities will be sufficient to provide an understanding of the situation at the department. Nurses point out, however, that even when the hatch is not used as a tool for coordination with physicians, it is useful as a place to put Emergency MRs as a reminder to oneself when interrupted in the preparations of some treatment.

Thus, it seems that the explicitness of information is not only affected by the amount of shared context, but also by staff members’ perceived degree of workload at the department, where less workload means less explicit information. Calmer periods will mean less input to the cognitive system, and therefore less amounts of information to handle. The previously discussed case where a nursing staff care team working a quiet shift at the ER did not bother to write all information in the patient list illustrates this principle. At the CAAU, nursing staff members measuring a parameter value will at times skip noting it in their report papers, instead memorizing the value and wait until coming back to the module to write it down in the patient binder or Electronic MR.

Apart from physical tools to make information explicit in the face of increasing workload, the staff at the PED does also have immaterial tools for communication. One such tool is “S-BAR”, a guideline for verbal reporting with the aim of making communication in the healthcare domain more structured. S-BAR is an abbreviation for the Swedish words “Situation”, “Bakgrund” (Background), “Aktuellt tillstånd” (Current state) and “Rekommendation” (Recommendation), indicating the order in which information regarding a patient should be told. This tool is intended to be used primarily during emergency situations, when workload can be assumed to be very high and when it is crucial that no piece of information is forgotten. Another communication tool
employed at the PED is cross-checking as described by Hutchins (1995b), where a listener confirms that the correct information has been perceived by repeating a spoken message. This type of communication is known as “loop communication” at the PED, and according to the supervisor, it is also intended to be utilized during emergency situations.

With increasing input to the system, the amount of tasks performed simultaneously at the PED will increase, thereby leading to increasing interference from staff members performing tasks close to each other. Sometimes, as many as five or more people might be in the same office, one of them perhaps making notes while the other are engaged in two conversations at once. This problem was to a great extent solved by the renovation, when the old office crowded with both nursing staff and physicians was replaced by separate modules and offices, but there are still many people using the same space. Nurse handovers are also occasionally held in the staff dining room, where other staff members come and go, talk about other matters and watch television. In this noisy environment, making shortcuts such as skipping the buffer created by noting a parameter value might be somewhat risky since chances are high to be interrupted by a question or favor from another staff member, even on the short route from a patient room to a module.

One purpose of using tools such as the plastic clip system at the ER to a greater extent when workload is higher is therefore to off-load the verbal information channel otherwise used most frequently. Information redundancy can also be created by multimodal communication, utilizing the embodiment of cognition. At one point, a nursing assistant was instructed by a physician to do an electrocardiography together with a nurse. The nurse was on the phone, however, so the assistant informed her by simulating the placement of electrodes from her own heart down to her arm. In another case, the door to a module was closed during a nurse handover. Another nurse wished to inform the new care team that a patient’s temperature had been measured, without interrupting the handover. Instead of opening the door, the thermometer was held up against the glass window so that the display was visible from inside, enabling the nurse of the new care team to make a note in the patient binder.

5.3 Summary
The overall goal of the PED seen as a cognitive system is “to ensure that the proper treatment is given to all patients in need of acute care”. The following sections summarize the ways in which this goal is achieved at the representational and implementational level of the Three-Level Analytical Framework.

5.3.1 The representational level
New patients arriving to the PED are input to the cognitive system. The representation of a patient’s health state is transformed through a bottom-up process by nursing staff from the initial reason of contact with the PED, going to the values of vital parameters, then to color representations which finally represents a priority. A top-down process begins where physicians look up the color representation together with reason for contact before assessing the patient’s health state. Patients are then either sent home directly, transferred to another department or transferred to the CAAU. In the latter case, patients go through another process, represented in the Electronic MR where medication and other treatment is written and then decoded by nursing staff into specific work tasks. Eventually, patients are healthy enough to be discharged from the PED, creating output from the cognitive system.
Coordinating the flow of representations is enabled by rules and guidelines, but very few physical constraints exist, making the cognitive system highly flexible. Guidelines also endorse using “common sense”/experience and there are many possibilities to make exceptions to work routines, such as overtriaging or omitting steps in the triage process. Normally, however, coordination is guided by a number of tools. At the ER, the tangibility of tools is prominent, such as the wall where paper-based Emergency MRs are placed, indicating current priorities that guide actions of the staff members. There is a need for fast information transfers, which is enabled by close proximity between people and tailored solutions such as the colored paper clips giving a quicker visual indication of patients’ priorities. At the CAAU, actions are relatively more long-term and workplaces are distributed over longer distances, requiring use of the intangible Electronic MR system which coordinates work by making information accessible everywhere. More frequent activities, however, are coordinated with tangible tools such as patient binders and report papers.

All throughout the PED and especially at the ER, rich verbal communication accompanies written communication, often used to clarify fragmentary written information. The nurses at the CAAU also coordinate activities written down on personal report-papers through frequent verbal communication. Body language can sometimes also be employed to convey messages otherwise hard to describe. Both physicians and nurses take active part in discussions and decisions, although physicians seldom make written notes, instead relying on nurses to serve as a “human interface”, collecting relevant information.

The explicitness of communication varies greatly: Verbal messages frequently include implications relying on common medical knowledge or common knowledge of a patient’s medical background. Written communication on the other hand tends to be more explicit the more distributed it is, with the Electronic MR highly explicit and decontextualized, the patient binders including some context-specific “codes” and the report-papers entirely personal and incomprehensible for others.

5.3.2 The implementational level

The computational task of treating a patient at the PED begins with the nursing staff’s computation of a triage priority, leading to the physicians’ computation of a suitable treatment which then leads to new assessments of patient health state. Prescriptions include a number of computations, where the physician calculates proper drug dosage after which a registered nurse prepares the drug. Normally the nurse has no insight into the dosage computation, but history of computations can be included, facilitating error detection. A last defense against overdosing also comes in the shape of a visual representation of the dosage. In an emergency situation, a precomputed rule of thumb exists at the emergency table to enable “quick-and-dirty” dosages that are sufficiently accurate.

Tools for computation shape the ways in which staff members think, as seen for instance by the way in which patients “are” colors in the triage system or room numbers at the CAAU in the minds of staff members. Furthermore, the design of the Emergency MR is closely linked to the process of triaging, demonstrated by the tendency to miss filling in the “weight” field in the MR, which is not an integral part of triaging.

The physical workplace affects cognitive activities, as seen in the intelligent use of space when placing objects close to each other as a visual cue, or the way in which many Emergency MRs close to each other gives a clear indication of current workload. Workload, however, needs to be sufficiently high in order for some tools such as the plastic clip system to be utilized, suggesting
that staff members rely more on internal memory during periods of relative calm. This can be risky, however, since information interference is common and hard to predict. During high workload, multimodal communication by use of embodied cognition and visual representations is utilized more frequently to off-load the verbal information channel. Immaterial tools for communication such as S-BAR and cross checking are also employed during emergencies to make verbal communication more explicit in order to protect against interference.
6 Cognitive Systems Engineering analysis

In order to analyze the PED as a joint cognitive system according to Cognitive Systems Engineering, the Extended Control Model (ECOM) was used (see section 2.2.4). Just like a Three-Level Analytical Framework analysis begins with identifying the goal of the cognitive system, an ECOM analysis begins with identifying the goal of the joint cognitive system. Since both analyses were performed on the identical case study, the joint cognitive system should be equivalent to the cognitive system described in chapter 5. Consequently, the identical goal was set as the starting point of the analysis, “to ensure that the proper treatment is given to all patients in need of acute care”. In order to achieve this goal, the joint cognitive system must control the process of receiving the patients in need of acute care and either treat them or transfer them to the proper department.

The goal of the joint cognitive system is quite complex and multi-faceted, and in order to provide a useful CSE analysis it needs to be split into meaningful sub goals with their own processes. In the simple Contextual Control Model (COCOM), control is kept by having the right construct to choose the right actions and evaluate their outcomes, as well as the required competence to be able to execute the chosen actions. By using these concepts as a guide, I identified four sub goals in total, of which two are needed to build a construct and the other two to build the required competence.

**Goal 1: Building a construct**

- Sub goal 1: *Understanding the patient state* – getting the necessary information about the health state of each patient to do the right treatment.
- Sub goal 2: *Understanding the workings of the system* – training staff so that they know how to make use of the patient state analysis, as well as monitoring risks and analyzing incidents in order to learn from previous experiences.

**Goal 2: Maintaining competence**

- Sub goal 1: *Having the adequate staffing* – making sure that enough staff has enough time to perform the necessary actions under varying patient load.
- Sub goal 2: *Having the adequate equipment* – ensuring that there is sufficient supplies of medication, other equipment and that there are enough beds, as well as checking that everything is fully functional.

For each of the four sub goals involved in the PED, a separate ECOM has been used to illustrate the multilevel process involved in achieving the sub goal. Naturally, the categorization into distinct processes is purely symbolic: They all happen simultaneously, and there are several important interrelations between them. These interrelations will not be included in the graphical depictions of the model, instead I expand upon them in running text.

According to Hollnagel and Woods (2005), a model of a system must be detailed enough to match the variety of the system itself. When it comes to ECOM, this means that the exact number of levels of control-loops may vary depending on which aspects of the system that one wishes to include in the analysis (see section 2.2.4). Common for all sub goal processes in this analysis is that the lowest level, the *tracking* loop, has been excluded. This loop corresponds to automatic and unattended activities performed by individuals through closed-loop control, and consequently I deemed it to be of a lower level of detail than necessary to understand the overall functioning of the PED seen as a joint cognitive system. More fine-grained research methods such as video
recordings would have been necessary in order to conduct a successful study of the tracking control level.

6.1 Understanding the patient state

Naturally, the primary means of ensuring that patients are given the proper treatment is to get an understanding of their health states – treating patients and evaluating the process is the core activity that takes place at the PED. Because of the unexpected nature of acute healthcare, the time span of activities is relatively limited, with no possibility to plan ahead for more than a couple of days. Therefore, the “targeting” loop of the ECOM has been left out together with the “tracking” loop, as seen in Figure 6.1.

Figure 6.1. ECOM - Understanding the patient state.

6.1.1 Monitoring

The control-loop for analyzing patient state at the monitoring level centers around the daily meetings between the members of the PED staff: rounding (physicians and nursing staff), morning meetings (physicians from all departments at the Children’s Hospital) and nurse handovers (nursing staff care teams). It should be noted that complete information about the state of each patient and the treatment that has been performed is supposed to be updated in the medical records, both the paper-based Emergency MR and the Electronic MR in the case of the CAAU and other departments at the Children’s Hospital. This means that each individual in the staff at the PED could theoretically get all needed information without having any meetings with other staff members. However, in practice this would not be possible without having to deal with an immense information overflow, and it would still risk that something important was accidentally missed. The major purpose of the meetings, therefore, is to communicate the most vital information in order to build a shared construct.

The physicians’ morning meetings provide the most far-reaching information regarding the state of patients on all departments, however it is in principle a selective summary, typically just covering any cases deemed unusual. This means that the physicians at the PED have no real
control over what information they will get here, but it also serves to prevent from information overload.

Rounding at the CAAU is a much more thorough process, beginning with physicians reading the latest entries on each inpatient in the Electronic MR written by the nursing staff prior to the round. Thus, the nursing staff controls the amount and type of feedback to the round by deciding what information to include in the Electronic MR. However, the whole medical history of the patient is accessible in the Electronic MR, providing an optional source of feedforward that might be crucial to the decisions regarding future treatment. Especially important information, like hypersensitivities and allergies, might have been marked by a physician with a warning, indicated by a small red symbol lighting up on the computer screen and ensuring that this feedforward will be noticed.

During the following verbal discussion of the round, physicians ask questions to the nursing staff, getting more detailed feedback where requested. It should be noted that although both a pediatrician, doctors-in-training, a registered nurse and a nursing assistant attend the rounds, there seems to be an implicit rule at the department that the only people really needed are the pediatrician in charge and the registered nurse of the care team. The pediatrician is the one asking questions and giving prescriptions, and the nurse is usually the one active in replying. On occasions, the nursing assistant will leave the round to do other tasks. Although the construct is shared between people, this means that sharing is not entirely equal.

Nursing handovers have a varying structure, ending up somewhere between being summaries of overall patient state and going into details regarding individual patients. During verbal handovers, the registered nurse of the previous shift is the one doing the reporting and thereby has the most control over the information provided, although the new care team might ask questions to fill in gaps in their construct. All handovers at the CAAU also include the new care team reading previous entries in the Electronic MR, allowing them to get more detailed information regarding every patient.

Control actions at the monitoring level are performed by the physicians. Based upon the shared construct built during morning meetings and rounding, decisions are made to either discharge patients, transfer them to other departments, continue with current treatment or write new prescriptions. These control actions form the objectives of the underlying regulating loop.

6.1.2 Regulating
The control-loop at the regulating level is concerned with context-specific aspects of patient state evaluation as well as executing the administering of medication and other types of treatments. This loop basically involves the actions of the nursing staff care teams and their day-to-day work routines.

In order to get feedback on the current process of the loop, nursing staff members make regular checks of patients’ vital parameters. Unexpected events also occur, such as patients pushing the alarm button or new patients arriving to the PED. The feedback constantly updates the individual care team member’s understanding of the process, and by making notes on report papers that can be transferred to the patient binder lists, the feedback serves to build a shared construct in the care team, which can later provide feedback to the monitoring loop.
On some occasions, a major change of a patient’s state might prompt the care team to write a note directly into the Electronic MR and contact the physician in charge to recommend an altering of a prescription or the discharge of a patient, thereby intervening with the monitoring loop. Furthermore, there is also a so-called “general medication list” which consists of a number of drugs that registered nurses are allowed to administer without a physician’s permission. This increases the variety of the nurses’ possible control actions, strengthening their competence and allowing for quicker adjustments to changing conditions.

When new patients arrive, the process of triaging with metts-p is used to build an initial construct regarding their health state. Unless the patient is immediately given a blue color priority, the triage process always includes checking the same vital parameters connected to the ABCDE mnemonic, regardless of the condition of the patient. These parameters are well known to be vital for life, and could be said to function as a sort of built-in feedforward to the control-loop. Interestingly enough, this provides a stronger construct since it requires the checking of potentially important parameters that might otherwise have been omitted, but at the same time it also creates a model of the patient state which conceals the real complexity by narrowing it down to a few parameters. One physician points out that patients might get a low priority on the triage and suddenly get much worse because of a latent condition. The nursing staff also expresses awareness of this, some nurses pointing out that experience must be used as a complement to the triage system, commonly known in the healthcare domain as the “clinical eye” of a practitioner. In cases where there is no clear match to a priority color or where it is apparent that a patient is in a critical condition, the nursing staff increases the variety of their control actions by skipping some parameter checks or selecting a higher priority than necessary, verbally informing physicians of the circumstances to create a more stable construct.

Prescriptions written in the monitoring loop give the objectives for the regulating process, but they are often underspecified, leading to information underload - the registered nurses responsible therefore often have to go back to the responsible physician to ask further questions, or make some interpretations regarding the exact method for administering. According to the supervisor, the aim is for all prescriptions to be so detailed that “there can be no hesitation”. The nurses agree, however they also view the interpretations of prescriptions based on their own knowledge and construct to be a necessary solution, and preferable to frequently having to contact physicians for more information. Physicians, on the other hand, endorse double checks by nurses. From a CSE perspective, double checking would be useful for sharing one’s reasoning and intentions, building a more solid construct, while being able to do some interpreting allow for more variety to the nurses’ control actions, meaning that clearer prescriptions should be a complement rather than a replacement.

As mentioned in section 4.2.5, even small deviations from a prescribed drug dosage could have severe consequences when treating small children, and the Electronic MR has no alert function to provide feedback when there is a risk of overdosing. One strategy for coping with the complex task of administering drugs is by having the physician spell out the two formats of drug dosage in the prescription. Normally, the prescription would be written in the form “100 mg/ml” (drug strength), “2,5 ml” (drug dosage). By instead writing drug dosage as “2,5 ml = 250 mg”, the physician makes the reasoning behind the prescribed dosage explicit, sharing construct with the nurse and making it easier to detect any incorrect calculations. It also follows the CSE principle of visualizing complexity instead of concealing it. This strategy, however, is not very widespread.
among the physicians and many nurses do not know of it, instead relying on their experience to help them detect any incorrect dosages.

A much more common strategy is the use of double signing, which is a process required at the PED when administering more potent drugs. Double signing means that two registered nurses must sign the administering of a drug in a special binder kept in the medication room. One nurse makes all preparations without the other one watching to ensure that their judgments are independent of each other, and then both nurses check that everything seems to be correct. The routine is another example of how shared reasoning helps to build a shared, more robust, construct. In practice, however, situations where time is insufficient might require efficiency over thoroughness, leading to the omitting of the routine in order to increase variety of control actions. According to one nurse, however, this usually happens when urgent situations arise at the ER, which means that the physician will be present to confirm the administering of a drug. Other times, compromises are made such as one nurse making all the preparations and another nurse administering the drug at a later moment, or the confirmation simply being done verbally between nurses to quicken the procedure.

6.2 Understanding the workings of the system
The second sub goal for building a construct at the PED is concerned with gaining the necessary experience and knowledge to complement the understanding of the patient state. This could be likened to having (or being) a sufficiently advanced model of the system, to understand how it works. Understanding the patient state is achieved by observing process changes and discussing them to build a shared construct, but a model of the system is also needed in order to anticipate the effects of various control actions. Since everyone working at the PED is a professional care giver, medical and nursing knowledge is to a great extent achieved beforehand through education. Learning is a continuous process, however, and understanding the specific nature of pediatric acute healthcare in particular is naturally of great importance at the PED. Furthermore, the whole joint cognitive system must also have an understanding of the overall workings of the system beyond that of medical and nursing knowledge, necessitating constant attention to the risk of potential functional breakdowns. The ECOM for understanding the workings of the system is illustrated in Figure 6.2 below.
6.2.1 Targeting

At the targeting level, system functioning is observed and analyzed in order to provide goals for the underlying control-loops. In 2005, a major reorganization at the Linköping University Hospital led to the introduction of a computerized deviation reporting system, a system for undertaking risk and event analyses in connection to larger changes and deviations as well as the formation of the Patient Safety Unit with the task of investigating the process of patient safety development. This also led to the Children’s Hospital getting a patient safety developer, responsible for ensuring that reports and analyses are conducted and that the recommendations from earlier analyses are implemented. The patient safety developer is supported by so-called “deviation coordinators” at each department, who have a better insight into the deviations that occur at their respective workplace. At the PED, one registered nurse and one nursing assistant assume the roles of deviation coordinators. The patient safety developer is the role mainly involved in the targeting control-loop, observing long-term risk trends by getting investigation reports from the Patient Safety Unit at the hospital as well as compiling the results from risk and event analyses. The supervisor at the PED performs similar tasks, but focuses mainly on the own department and collects more specific information. The extent to which the staff adheres to hygiene rules, for instance, is measured by letting staff members observe each other during day-to-day work and count the percentage of care acts where hygiene rules were strictly followed.

Once every month, the patient safety developer holds a meeting between the supervisors and deviation coordinators from all departments of the Children’s Hospital, where such statistics are analyzed and experiences are exchanged between the departments in order to build a shared
construct regarding the functioning of the joint cognitive system. The deviation coordinators of
the PED, normally working with day-to-day tasks at the department, now have the opportunity
to provide the construct of the higher control-loop with updated feedback from lower levels.
Similar meetings are held locally at the PED by the supervisor every week, known as workplace
meetings, with the purpose of providing updates on any news regarding the department and
discussing them with members of the staff, providing a feedback link to the supervisor. However,
only a handful of the staff is present at the PED during workplace meetings, and in practice, the
only ones that are able to attend are those who just ended their shift. Furthermore, physicians
seldom seem to attend these meetings, all in all leading to an incomplete construct.

The information gathered by the supervisor at the workplace meetings is distributed in the form of
notes to all staff members by e-mail, together with updated routine descriptions and memoranda.
This control action serves to share the construct regarding system functioning to all people
working on lower levels, however the supervisor admits that this easily leads to information
overload and that there is no sure way of knowing that everyone reads it. All routine descriptions
and memoranda are therefore stored in a database accessible to all staff members, and the
information deemed most important is also printed and put in a “good-to-know” binder, located in
the staff dining room. Additionally, the coordinator is responsible for making sure that all paper-
based information in modules is up to date. The supervisor’s construct is also the basis for
developing so-called scorecards, summarizing the current status and target of five different aspects
of organizational development at the Children’s Hospital, including patient safety development.
These scorecards are put on the wall in the coordination office and provides target levels for
different aspects of the joint cognitive system functioning.

Targeting level control actions also include long-term training activities. Since a couple of years
back, Linköping University offers registered nurses a specialist education program in pediatric
care. This education cannot be said to be controlled by the PED and therefore falls outside the
scope of the joint cognitive system, but since several of the nurses have undergone the program, it
becomes relevant. At the PED, training courses are given to all staff members when a new piece of
medical equipment is introduced. New members of the staff also have a whole year’s introduction
to the department, beginning with a five week long “period of adjustment” under supervision of
an experienced staff member. Furthermore, every new member of the Children’s Hospital staff
goes through a one day simulation training course in emergency healthcare. The course goals are
to learn how to use medical devices in emergency situations as well as to train the ability to
cooperate and to utilize structured thinking. The latter is supported by the use of the ABCDE
mnemonic also used in triaging with metts-p. Training takes place in a room similar to the
resuscitation area of the PED equipped with a child medical simulation mannequin, capable of
simulating breath, screams, heartbeats and pulse. The room is also equipped with an emergency
cart containing various medical devices and a telephone for requiring additional resources,
everything designed to make the scenario resemble a real life emergency situation. In each
scenario, the course participants must work as a team consisting of both physicians, registered
nurses and nursing assistants, each doing their part in stabilizing a patient with a life threatening
condition. After each scenario, the team has an evaluation session, going through the case step by
step and writing down positive experiences. The scenarios are also videotaped by the instructors so
that certain moments can be analyzed in detail. The evaluation finishes with both training
participants and instructors going through any aspects that could have gone better during the
scenario. According to the scorecard concerned with patient safety development, the aim is to let
all staff members repeat a shorter version of the emergency training course once a year, as well as train cardiopulmonary resuscitation (CPR) once every second year. Additionally, shorter emergency exercises are held at the PED about once a month.

These training courses all serve to expand the construct of the staff to encompass situations not covered during basic education: The equipment training courses provide specific knowledge for how to use the medical equipment at the PED, and the specialist education at the university deals with things such as getting familiar with reasonable drug dosages to children of different ages. The emergency training course is especially useful, since it provides training opportunities on scenarios that will very rarely occur for real, and for which natural experience therefore is very hard to come by. By having the training course, the joint cognitive system can extend the mental model of staff members, making it encompass the whole range of variety that comes from patients arriving at the PED.

Finally, the patient safety developer goes through deviation reports in the computer system, serving as feedback from the monitoring loop as indicated by the arrow in Figure 6.2. The supervisor and patient safety developer then together judge which deviations that require a more detailed investigation and initialize risk and event analyses to gain more information about the workings of the system which can be feedforwarded down to the underlying loops.

6.2.2 Monitoring
While the analyses at the targeting level are infrequent and focus on investigating the most severe risks and events, the monitoring level is concerned with observing more common deviations of normal system functioning. Feedback regarding these deviations comes from continuous interactions with the system during day-to-day work, as shown in Figure 6.2 by the arrow leading up from the regulating control-loop. Deviations are reported by any staff member, and handled by the deviation coordinators. However, reporting a deviation is not simply a matter of observing it, but also of having the right construct to be able to determine that a report is required to begin with. Experience might be assumed to give staff members the necessary feedforward to build this construct, but it remains uncertain, since there is no clear-cut definition of what constitutes a deviation.

Apart from writing reports on observed deviations, other control actions included at the monitoring level are to regularly check the identity of each patient. Prior to meeting a patient, nurses at the ER are expected to print a sticker with name and national identification number, attaching it to the Emergency MR and asking the patient (or the patient’s parent) to report the number before triage begins. At the CAAU, patients get an ID wristband when hospitalized which is then supposed to be checked every day and signed in a special field in the Electronic MR database. This widespread routine is naturally meant to keep the construct of the staff updated, preventing the risk of giving the wrong treatment to the wrong patient. However, this update only happens once every day, while the risk of selecting the wrong patient in the Electronic MR system is prevalent every time a treatment is to be given. Furthermore, one nurse points out that the name and ID of a selected patient are not particularly clearly displayed on the Electronic MR, providing little support for the building of a construct regarding patient identity.

6.2.3 Regulating
The process of analyzing patient state discussed earlier also fills the purpose of providing nursing staff members with indicators of any risks of a functional breakdown at the regulating level. The
issue at this level is not determining that a deviation should be reported, as is the case in the monitoring loop, but rather to actually observe risks in the first place, providing feedback to the monitoring loop. Similar to deviations, there is no clear-cut definition of a risk, making identification of them problematic. A suggested way of strengthening this capacity was introduced during my case study by the supervisor: Aiming at encouraging risk awareness, two so-called “risk jars” were placed at both modules, where nursing staff members are supposed to put notes regarding any risks they observe during a shift.

Making the staff aware of risks could also be believed to lead to higher adherence to safety rules, such as hygiene routines and various memoranda. However, this is not always practicable, as seen by the workarounds of the double signing discussed in section 6.1.2, which is in line with the ETTO principle. Hygiene routines (always washing hands with disinfectants before and after care acts, sometimes using an apron and gloves) is another example where certain situations make them impractical, such as holding a report paper or medical equipment in your hands when entering or leaving a patient room. Another peculiar effect that I observed is that adherence to hygiene routines seems to be affected by the behavior of other staff members: During rounding, when as many as seven people might visit the same patient, every person entering the room is more likely to adhere to the hygiene rules if the persons before did it. This phenomenon needs further support to be confirmed, but it seems clear that adherence to safety rules is affected by factors such as the ETTO principle and group size, something the quantitative measurement of hygiene rule adherence used in the targeting loop fails to embrace, thereby leading to an incomplete construct.

6.3 Having the adequate staffing

The first sub goal for maintaining the necessary competence at the PED is concerned with staffing – naturally, there is no use in building a construct to understand what control actions should be performed if the controller of the joint cognitive system is incapable of performing these control actions, and at the PED, the controller consists of the staff. This is not only a matter of the quantity of available staff, but also the experience of its members, linking it closely to the sub goal of understanding the system discussed above. Since the staff capacity needed is dependent on the current workload at the department, achieving this sub goal will also be inextricably linked to the concept of patient load, including both the sheer number of patients as well as how demanding each patient is in terms of effort from the staff.

Even though the patient load at the PED can change quickly, activities such as requesting additional resources are generally not performed on a shorter time scale than at the monitoring level. Therefore, both the regulating and the tracking control-loops have been left out in the ECOM illustrating this sub goal, as seen in Figure 6.3:
6.3.1 Targeting

The issue of controlling staffing at the targeting level mainly concerns the supervisor of the PED, who has the ultimate responsibility for ensuring that the department is capable of meeting its demands. In order to build a construct regarding the long-term patient load trends, feedback is provided in the form of statistics regarding the number of visits each year. Furthermore, the number of visits that required a full medical examination by a physician are counted separately, expanding the construct to also include some understanding of patient demand. At the CAAU, where inpatients stay longer, statistics are instead based on the number of care periods and the average number of days for each care period. Although these statistics might be used to predict possible future bed crunches, it is likely that by themselves they are still too crude to account for the complexity of acute healthcare. There are, however, some known correlations between certain time periods and the number of people catching particular diseases. One such example is the increase of children catching the respiratory syncytial virus (RSV), which as I mention in chapter 4 is known to happen during March, the time of my case study at the PED. This provides the department with an important source of feedforward, since it means that the specific medication and equipment used for treating RSV can be prepared beforehand (see section 6.4.1). Naturally, patients with other diseases will not stop coming during such a period, but with the extra patient load comes higher predictability.

Together with the coordinator, the supervisor uses the achieved construct regarding future patient load and compares it to the current staff resources. The coordinator then proposes a schedule to be approved by the supervisor, and decisions are made regarding recruitment of new staff members when deemed necessary. It should be noted that scheduling is only done for the nursing staff – physicians will have an independent scheduling also taking into account their part time work with appointments at the main office of the Children’s Hospital, and therefore lie outside the control of the PED.

6.3.2 Monitoring

The staffing activities at the monitoring level include observing the changing patient load during the course of each shift, supported by the verbal meetings and use of tools such as the patient
chart at the CAAU and the patient list as well as the plastic clip system visualizing triage at the ER. The coordinator has the task of continuously getting updates from the other staff members, determining if additional resources are needed. The total amount of patients visiting the department is documented and eventually ends up as the statistics providing feedback to the targeting loop, as seen by the arrow in Figure 6.3.

The coordinator role is also responsible for distributing the staff between the different work roles of each shift, using the long-term schedule as a basis. Some days prior to each shift, each staff member is assigned a specific work role at the ER or at one of the modules at the CAAU, written in a binder kept in the coordination office. The ambition is to match less experienced staff members with more experienced staff members in the same care team as far as possible. The coordinator’s short-term scheduling should be seen as a proposal – as the staff members of the shift arrive to the PED, they might do smaller adjustments. The actual distribution of the patients at the CAAU to each module in particular is left to the shift to decide. Here, the previous shift members provide feedback regarding the overall demand of each patient at the CAAU. A quick discussion is commonly held at the patient chart in the coordination office prior to the proper nurse handovers, building a shared construct regarding patient load and determining whether the patients should be split evenly between the modules, or if one module should take care of a lesser amount of more demanding patients. Another factor commonly involved is whether a staff member has treated a patient during previous shifts, termed “knowing” the patient. Staff members prefer working with patients they know, giving them use of their pre-existing construct to provide feedforward regarding the patient’s state.

Similar to the knowledge of recurring stress periods used as feedforward in the targeting control-loop, knowledge of common short-term trend cycles is used in the monitoring loop to anticipate patient load during a shift. An important strategy used here is knowledge about opening hours of health clinics – typically, parents of sick children will seek contact with their local health clinic, contacting the PED only as a second option. This means that patient load at the PED can be expected to increase during weekends and nights, when most health clinics are closed. Paradoxically, these are also precisely the time periods when the staff at the department is reduced, as described in section 4.2. In order to compensate for this, the staff at the PED can use two strategies: requesting additional resources to strengthen their competence by increasing the variety of their control actions, and trying to control the flow of patients, reducing the system variety.

Additional resources are available in a number of ways: First of all, members of the staff at the PED currently not working at a shift can be asked to work overtime. This naturally has the consequences of costing the department extra pay as well as in the long run leading to fatigued staff members. An increasingly common alternative since the creation of the Children’s Hospital is to require help from another department where patient load is currently lower. This solution, however, also comes with the issue of staff members with a different experience, lacking both full understanding of the workings of the PED as well as knowledge about acute healthcare, consequently having an incomplete construct. At other times, the main problem is not related to staffing but rather to a shortage of beds, connected to the sub goal of having adequate equipment discussed in section 6.4. In these cases, the reverse solution of placing patients at other departments might be used.
The second strategy, to control the flow of patients, is connected to the overall goal of ensuring the proper treatment only of patients in need of acute healthcare, thus aiming not to use up the competence of the joint cognitive system on healthier patients. The nursing staff and physicians working at the ER do have the option of refusing to receive a patient, but there is of course a risk of involuntarily rejecting someone who turns out to really be in need of acute care. Again, experience is crucial here, since it provides the necessary feedforward to determine which patients can be sent home directly. Consequently, the aim is to only let staff members with at least one year of experience at the CAAU work at the ER – however, this ambition had to sometimes be forfeited during the hectic March period that I observed.

6.4 Having the adequate equipment

Finally, maintaining competence at the PED is also dependent on having the adequate equipment, necessary for the controller of the joint cognitive system constituted by the staff in order to perform the proper control actions. In comparison to departments such as intensive care units, equipment used at an emergency department is relatively simple, but the unpredictability of acute healthcare instead places higher demands on the many different types of medication and tools needed. Whereas staffing involves both quantity and experience, having the adequate equipment in contrast involves both quantity and proper functioning. Below, the ECOM of the equipment sub goal is illustrated in Figure 6.4:

![Figure 6.4. ECOM - Having the adequate equipment.](image)
6.4.1 Targeting

Long-term handling of equipment has recently been placed outside the control of the PED through the use of a centralized supply system at the hospital. Each department chooses a certain set of medications and other equipment from a “base supply”, selecting those articles that are known to be used regularly. Each article corresponds to a certain bar code which is scanned by external staff, refilling equipment when needed. At the PED, the system seems to be functioning as intended, however it presupposes that feedforward can be provided regarding which articles that will be frequently needed. As discussed in section 6.3.1, some feedforward of this kind comes from knowledge of time periods when certain diseases requiring particular medication and equipment are more common. However, with the quickly shifting demands of the department, such feedforward is far from sufficient to foresee all system variety, and as a result the medication room at the PED has a large section named “A-Ö” (the first and last letter of the Swedish alphabet) for all drugs that need to be ordered outside the base supply whenever a patient requires it. These orders, however, can only be planned on a shorter time scale and therefore end up as part of the monitoring control-loop.

The PED itself only has full control over two loosely connected activities at the targeting level: to make sure that available medication is fit for use, and to update the general medication list mentioned in section 6.1.2. The first task simply consists of checking the expiration dates once a year on all drugs in the medication room. The second task mainly involves the physicians, who have the ultimate medical responsibility at the PED. This includes responsibility for updating the general list of drugs for which the right to administration is delegated to the nurses. Through day-to-day work, nurses gather experience regarding which drugs that will commonly be administered, which they provide as feedforward to the physicians together with requests for having these drugs on the list in order to increase the variety of their control actions.

6.4.2 Monitoring

At the monitoring level, the daily demand on equipment is controlled. The centralized system for getting deliveries from a base supply is fully outside the control of the PED when it comes to medication, but for other equipment the department must still place orders regarding the articles on which refills are requested. As mentioned above, there are also a large number of drugs in the medication room which are not included in the base supply. Whereas all members of the nursing staff are involved in ordering other equipment, a few of the nurses share the responsibility for ordering medication according to a rotating weekly schedule. This task is not entirely simple, as the drugs listed in the “A-Ö” section include both such that are regularly administered and others that might have been needed for a single patient with a rare disease, and which should consequently not be refilled. As a support, the responsible nurse gets feedback from the other nurses’ regulating activities through the use of a whiteboard in the medication room, shown in Figure 6.5:
Figure 6.5. The medication room whiteboard.

This whiteboard is checked regularly by the nurse responsible for ordering to get updated summaries on the needs. Despite the help of the whiteboard, however, I am told that there is occasionally a critical and unforeseen shortage of some drug, indicating that the feedback from the whiteboard is insufficient to provide an adequate construct. To solve this problem, nurses can extend the variety of their control actions by either borrowing supplies from another department, using supplies from the emergency cart or by ordering an instant delivery of the drug from the Hospital Pharmacy, which however will be much more costly for the department.

Each shift, the nursing staff is also supposed to check the equipment of each patient room, including everything from the supplies of gloves and aprons to the functioning of all technical apparatuses, and sign a checklist in the room. Likewise, there is a checklist for the emergency cart and the other carts are also supposed to be refilled at the end of each shift. Should any malfunctioning equipment be discovered, this is reported to the coordinator who in turn reports it to the central maintenance unit of the hospital. This routine provides a systematic way of observing any risk indicators and thus is crucial for achieving the sub goal of building an adequate understanding of the system, discussed in section 6.2. Oddly enough, I am told that the routine is completely adhered to at the ER, but not to the same extent at the CAAU, despite the fact that the same staff works at both places. However, the routine was more recently implemented at the CAAU, which might mean that it has not yet had the time to get established as part of the daily work tasks. Regardless, the routine is much similar to the triage color priority system in that it has a central strength and weakness: Its built-in feedforward regarding which items to check in a patient room ensures a consistent control of important equipment, but at the same time creates a model of the task which conceals the real complexity. This actually proved to be a real problem during my observation at the PED, when an alarm button at a patient room was discovered to be malfunctioning - a critical safety failure not covered by the checklist routine.
6.4.3 Regulating

Just as with the sub goal of building an understanding of the workings of the system, the sub goal of having the adequate equipment will also be incorporated into the day-to-day activities of the nursing staff members as they provide treatment to patients. Naturally, any equipment that runs out of supply or starts malfunctioning during the middle of a shift will prompt the staff member discovering it to briefly intervene with the monitoring control-loop, ordering a refill or reporting the malfunction.

As mentioned above, all nurses use the whiteboard in the medication room to communicate the need for refill of any drug that they have noticed to be of short supply during their regulating activities. There is no guarantee for this to be noticed every time a drug is administered, however, meaning that the nurses’ construct regarding the needs of refill might get incomplete, which in turn can explain why the feedback provided to the monitoring control-loop at times is inadequate. Nevertheless, a more rigorous system is used when it comes to medication that requires double signing, where the binder used for signing is also used to make notes regarding the amount left of the medication. This helps to ensure that the most important drugs are available, should they suddenly be needed to avert a critical loss of control.

6.5 Summary

The PED seen as a joint cognitive system in the CSE sense has a goal identical to the one identified in the DC analysis: “To ensure that the proper treatment is given to all patients in need of acute care”. This summary describes how the goal is achieved by controlling the multilevel processes of four different sub goals, each analyzed using a separate ECOM: Understanding the patient state, Understanding the workings of the system, Having the adequate staffing and Having the adequate equipment.

6.5.1 Understanding the patient state

This is the primary means of ensuring that patients are given the proper treatment. Because of the limited ability to plan ahead in acute healthcare, the targeting loop is left out. At the monitoring level, information regarding patients is shared as feedback at CAAU meetings, with nurses controlling what to bring up to avoid information overload. Feedforward comes in the form of a patient’s medical history in the Electronic MR. Physicians then make control actions in the form of decisions regarding future treatment.

At the regulating loop, nurses perform regular checks of patients’ vital parameters, frequently updating a shared construct. A “general medication list” increases the variety of their control actions by allowing some drugs to be administered by nurses without permission from physicians when deemed appropriate. At the ER, construct is built by the process of triaging – the structured way of checking parameters functions as a built-in feedforward, indicating which parameters that are important to check and thereby reducing the risk of omitting information. However, the real complexity of a patient’s health state is also concealed by the metts-p triage tool which requires a so-called “clinical eye” as complement. Control actions at the regulating loop include the nurses administering medication, which involves interpreting sometimes underspecified information from prescriptions. When administering more potent drugs double signing is used to create a more robust construct.
6.5.2 Understanding the workings of the system

This sub goal concerns complementing the understanding of the current patient state with knowledge about pediatric acute care as well as the joint cognitive system as a whole, including checking risks for functional breakdowns. At the targeting level, meetings are held between the patient safety developer, deviation coordinators as well as between other members of the department where experiences are exchanged and trends based on deviation reports analyzed, building a shared construct and in the long run guiding decisions on further risk/event analyses. Training courses are also held to expand the mental model of staff members, making it encompass rare emergency situations, technology used at the department as well as specifics of pediatric care.

The monitoring level is primarily concerned with observing deviations in daily work and reporting these as feedback to the control level above, an activity which requires experience from the staff since no clear-cut definition can be given as to what constitutes a deviation. Feedback to the monitoring level is in turn provided by the activities at the regulating loop, where risks are observed during day-to-day work. At this level, it also turns out that adherence to some of the safety rules of the department is not always practicable but rather dependent on factors such as the ETTO principle. The quantitative measurements at the targeting loop fail to embrace this, leading to a partially incomplete construct at that level.

6.5.3 Having the adequate staffing

In order to match the current patient load, the PED seen as a joint cognitive system requires competence in the form of a staff, both in terms of the quantity of staff available staff members but also their experience. Control actions are performed at the targeting and monitoring time scales, meaning that both the other two have been left out. At the targeting loop, feedback from statistical records on patient load is assessed by the supervisor to get a crude understanding of future staff requirements. Some feedforward is provided in the form of well-known correlations between certain periods of time and particular diseases. Based on this construct, scheduling is done for the nursing staff together with the coordinator.

The coordinator also does short-term scheduling at the monitoring level, striving to match experienced and inexperienced nursing staff in the same care team as well as balancing the number of patient as well as patient demand for the care teams. When patient load is too high, one control action is to require additional staff, which might lead to fatigue/extra costs or to having to rely on staff with an incomplete construct. System variety might also be reduced by refusing to receive more healthy patients, however this requires experience from the staff at the ER in order not to involuntarily deny treatment to someone really in need of acute care.

6.5.4 Having the adequate equipment

The final sub goal concerns the ability to have the adequate quantity and proper functioning of equipment, including both medication and tools. There are two loosely connected control-actions at the targeting-level: to check medication dates once a year and to update the general medication list based on feedforward from nurses regarding which medication that frequently is administered. A centralized “base supply” system at the hospital puts long-term refilling of equipment outside the control of the PED as a joint cognitive system.

At the monitoring level, day-to-day use of some equipment and medication is checked. The unpredictable nature of acute care means that many types of medication still have to be ordered outside the base supply system. Keeping track of current demand here is challenging, and
sometimes there occurs a critical shortage which requires nurses to borrow medication from other departments, from emergency carts or by ordering an instant delivery. Nurses also check room and cart equipment using checklists, a routine strengthening their construct but that might increase the chance of missing to notice other risks.

At the regulating loop, use of equipment during daily activities is noticed, with nurses intervening with the monitoring loop should some equipment run out of supplies. When administering drugs requiring double signing, part of the routine is to make notes regarding the amount left, in an effort to make sure that there will be no shortage of these more important drugs.
7 Resilience Engineering analysis

The following chapter describes the Resilience Engineering analysis of the Pediatric Emergency Department, based on the analyses of the two previous chapters as well as on data which was excluded from these analyses. The department’s potential for resilience is analyzed by describing each of the four capacities responding, monitoring, anticipating and learning one by one in that order.

7.1 Responding: Dealing with the actual

When analyzing the functioning of any system, it seems straightforward that the starting point should be the mechanisms operating on real-time events – all other mechanisms are useless unless there is a way to deal with the actual. The capability to respond is the aspect of resilience that is concerned with these mechanisms, both at the sharp and blunt end. Indeed, this is the main part of a typical CSE analysis, and even more so a DC analysis.

7.1.1 Ad hoc adaptations

The DC analysis showed that the constraints coordinating activities at the PED are principally of a symbolic nature, such as abstract rules and a range of tools serving as templates for how information should be written. This property gives the department a very high degree of flexibility, providing ample opportunities for ad hoc adaptations. In CSE terms, this flexibility comes from having a great variety of control actions, and the CSE analysis also identified several examples of strategies for obtaining this: When under time pressure, the doublesigning or some steps in the triage process can be skipped, and when patient load is high, additional resources can be requested from other departments of the Children’s Hospital and the staff members of the PED can be required to work overtime. In the face of imminent dangers, this adaptive capability can be used to promptly bypass logical constraints in line with the general principle “you do what you have to do to save lives”. Flexibility is furthermore not only highly praised by the staff members working at the sharp end, but also reflected in tools such as the “general medication list” and some of the available written guidelines themselves, endorsing the use of “common sense”, knowledge and experience as complements to static rules. In general, strictly prohibiting rules are rare in the healthcare domain, and emergency departments in particular will be designed with the capability to respond to ever-changing circumstances in mind, leading to a promising potential for creating resilience at the sharp end. If there was a motto for acute healthcare, it would be to “expect the unexpected”.

A closer examination of the tools used for coordination at the PED revealed that one aspect crucial for obtaining flexibility is tangibility: This is the aspect which allows objects to be tailored with ad hoc solutions such as the plastic clip system and post-it stickers. Furthermore, the structure of the physical environment itself is closely linked to the flexible nature of work tasks: At the ER, where the situation quickly changes, a built-in flexibility is provided by placing staff members close to each other, facilitating faster information updates and decisions as well as a richer verbal communication. Multimodal communication also appears to be an important tool for facilitating adaptive capacity by creating information redundancy – verbal communication could be said to serve as a “glue” to fill in gaps in written communication, and when physical constraints or information interference prohibits efficient verbal communication, body gestures can be used as a complement.
From an RE perspective, however, adaptive behavior will not be invariably beneficial – optimizing the system to match highly specific circumstances will risk making it more brittle when facing other, unthought-of hazards. The DC analysis showed that the adaptive capacity is closely linked to the use of common ground and shared context, relying on information to be implicitly understood by staff members and possibly leading to ambiguity and loss of important communication if maladaptive. As noticed by Cohen et al. (2006), communicating through implied messages such as personal abbreviations can lead to safety concerns. At the PED, however, this problem seems to be avoided by adapting the implicitness of communication itself to the situations where it is used – being more explicit when communicating with staff members of new shifts and when writing information to be distributed to more people. This is further enabled by the design of coordination tools used in different situations guiding the needed explicitness of communication: The Electronic MR requires information to be clear, precise and decontextualized, while report papers allow notes to be much more implicit and personal.

Furthermore, the perceived workload at the PED was also revealed in the DC analysis to be an important factor for the explicitness of communication. According to the ETTO principle from the CSE perspective, calmer periods would be used by staff members to fill in written information more thoroughly, and increased workload could conversely be assumed to put pressure on favoring efficiency over thoroughness, thereby reducing the explicitness of information. Paradoxically, higher workload at the PED actually seems to make information more explicit, utilizing the full potential of the Emergency MR plastic clip system to off-load the verbal communication channel, thereby countering increased information interference. This could be explained if the factor triggering explicit communication is not workload per se, but rather a perception of a more severe and risky situation. This interpretation is supported by the observation from the CSE analysis that information deemed as potentially safety critical is supposed to be entered into the Electronic MR system instantly, being the most explicit communication tool.

7.1.2 Ready-to-use solutions and generic competence

Whereas ad hoc adaptations are necessary tools for responding to ever changing conditions, ready-to-use solutions are useful for executing certain responses fast enough. In order to facilitate efficient cooperation across departments, much equipment at the Children’s Hospital such as emergency carts have standardized contents. The PED is also equipped with a wide array of regionally standardized memoranda, reviewed approximately every second year, and furthermore there are several written guidelines on all sorts of specialized procedures, updated by the supervisor and sent by e-mail to staff members as well as put in the “good-to-know”-binder. There is, however, no way of ensuring that these are read, and some staff members indeed admit to usually assessing a written guideline only right before having to apply it.

Nevertheless, the implementational level of the DC analysis revealed that the staff at the PED does have several tools providing pre-computations specifically designed for emergency situations, functioning as ready-made solutions and ensuring that response capacity is adequate when it is needed the most. The emergency table in the resuscitation area provides a fast way to administer sufficiently precise dosages of potent drugs, the communication tool S-BAR serves to structure verbal communication to reduce the risk of omitting important information and the use of loop communication checks that information is correctly understood. Furthermore, the metts-p triage system analyzed from a DC perspective is revealed to be a powerful tool for representing health states of all new patients as priorities, systematically computed through the Emergency MR
coordinating parameter assessments to follow the ABCDE mnemonic. New staff members lacking experience also learn to think according to ABCDE during the emergency training course. Similar to S-BAR, the mnemonic serves as a way to structure thinking, as put by one of the instructors: “If you’re lost, go back to A!” (= check the airway). Known to be the general priority order of emergency treatment, the mnemonic seems like an excellent tool for building a generic team competence, in contrast to highly specialized solutions applicable to a narrow range of situations.

7.2 Monitoring: Dealing with the critical

Monitoring the health of patients at the PED is achieved through the alarm system as well as the planned-ahead measuring of vital parameters by the nursing staff, propagating these representations over various tools as described at length in the Distributed Cognition analysis to eventually end up in the patient’s medical record. These representations serve as lagging indicators of the individual parameter values, becoming leading indicators of the overall patient state when being evaluated during rounding and other meetings between staff members. The primary monitoring tool for the physicians at the CAAU is the Electronic MR, usually updated prior to the two rounds each day. Even though many other departments only have one round per day, this still means that there might be a delay of up to the length of a whole shift before an event is observed and analyzed by the medically responsible staff. However, more critical changes might prompt nurses to update the MR instantly and verbally informing the physicians, intervening with the control-loop above as stated in the CSE analysis.

While these indicators are crucial for monitoring events at the sharp-end, they must be completed with indicators of events distributed far in space and time. This is where the database function of the Electronic MR fills its purpose, providing potentially vital longitudinal coordination. Apart from warning for past detections of risks such as hypersensitivity, the system also collects information from other hospitals and health centers that have been treating the patient in the past.

Monitoring safety at the PED includes other factors than patient state, however, as illustrated in the CSE analysis by the need to achieve three other sub goals. One of these is “having the adequate equipment” and as shown in the analysis, refilling medical instruments and medication is to a great extent taken care of by a centralized base supply system, outside the control of the PED and therefore by definition not part of the joint cognitive system. The medication supplies in the “A-Ö” section, controlled by the department, were revealed to be refilled without any strict system with the exception of the more potent drugs for which doublesigning is required. From an RE standpoint, this means that monitoring of the resources for building the capacity to respond is to a great extent based on experience. More crucial, however, is the fact that the PED is not monitoring the workings of the centralized base supply system, which could lead to sudden surprises. During my case study, the hospital pharmacy indeed ran out of adrenaline at one point, prompting them to call the PED but not until the supplies were already empty.

Some problems with the Electronic MR system regarding monitoring of other factors also become evident. The CSE analysis revealed that the name and ID of a patient are not considered clearly displayed in the electronic system by staff members, leading to a very real risk of accidentally administering a drug to the wrong person. This means that staff members will have to rely on their ability to remember the medication list of each patient. From a DC perspective, this could be achieved if the representation of the patient is associated with past interactions with the patient,
including administering of certain medications (which consequently leads to a reaction if the medication list assumed to belong to a certain patient does not match the expectations). Regardless, another problem remains when using the Electronic MR system administering drugs, namely that there is no warning against overdosing. Since calculation of dosage is a relatively simple process (for a computer, that is) and entirely based on the weight of a patient, available in the Electronic MR, there are no technical obstacles to the implementation of such a warning system. This problem is well known to the staff, however, and was identified in a recently finished regional risk analysis focusing on the medication module of the computer system, which might lead to the inclusion of this feature in future versions of the system. Until then, home-made warnings such as the picture with different-sized syringes (see Figure 5.5) testify to the desire to build a more resilient drug handling system at the PED.

7.2.1 Tools for thinking and experience

While there are apparent problems with monitoring indicators of safety such as patient identity and drug dosage, these indicators are objective, easily understandable and clearly defined. Tools such as the checklists for assessing room equipment and the metts-p triage system are attempts at defining clear criterions for more complex indicators – the question is, do they succeed? According to the CSE analysis, these tools have in common that they use built-in feedforward to decide upon a limited number of parameters known to be important to check, building a strong construct by ensuring that none of these are omitted but at the same time serving as models where some of the real complexity is concealed. The DC analysis provided further details regarding how the design of the Emergency MR shapes the way in which staff members do triaging, and how the weight parameter, not included in metts-p but vital for future drug administering, is easily forgotten. It seems possible, therefore, that the tool has a disadvantage in that it might make staff members more prone to miss vitally important information not included in the model. In one such case that I was told about, a patient showing no signs of illness except for a slight lethargy was given a green priority, then suddenly got much worse and eventually had to be transferred to the Intensive Care Unit. Furthermore, even if the vital parameters are assumed to be all-encompassing there is still a risk that a patient given green priority color will get worse simply by having to wait for up to four hours before being medically examined.

Interestingly, metts-p is generally seen by the staff as a useful tool for helping inexperienced staff to “know what to look for”, evident by the inclusion of ABCDE in the emergency training course, however many staff members also point out that a metts-p evaluation in turn needs to be completed with experience in order to deal with the cases that fall somewhere between the pre-defined ESS categories and priorities. Many use the slightly mystical term “clinical eye” to account for this ability to diagnose patients, assumed to be a sort of tacit knowledge associated with the craftsmanship of healthcare professionals, not fully understandable. In RE terms, professional experience could be understood as a way to anticipate future events based on familiarity of the current situation (providing feedforward in terms of CSE). This makes it a necessary attribute not only for medical examination but for a wide array of other ill-defined monitoring tasks, such as identifying risks and determining for which risks to write deviation reports.

7.2.2 Shared reasoning

As pointed out by Klein et al. (2005), however, experienced people might sometimes be more likely to fixate on an initial explanation and fail to detect problems. In a workplace where cognitive
tasks are distributed across many people, the key to overcome this problem lies in sharing
information: Hutchins (1995a) points out that the need to communicate brings with it the
possibility for more diverse interpretations of situations, and from a CSE perspective, it
strengthens the construct. The DC analysis made clear that rich verbal communication is a very
central means of coordinating activities at the PED, often completing fragmentary written
communication. The ECOM analysis showed that all constructs are not built with equal input
from all staff members, for instance nursing assistants seldom partake in the decision-making
during rounding, and physicians typically do not attend the workplace meetings. However, staff
members assert that the climate at the PED endorses everyone to take active part in discussions.
It should also be noted that the nursing staff, enjoying a relatively high degree of freedom, are
careful to always inform the medically responsible physician when deviating from a routine, such
as when skipping doublesigning.

With rich communication follows the problems of information overload, however. Every piece of
information cannot possibly be distributed to every staff member, so summarized interpretations
of larger chunks of information are instead propagated through the cognitive system by solutions
such as the nursing staff functioning as a “human interface” to physicians. This is somewhat
problematic from a CSE standpoint, however, since it becomes yet another way to conceal some of
the real complexity of a situation. For instance, physicians at the ER receive the Emergency MR
with a given priority color after triage has been finished, but they never look up the ESS code
chosen by the nursing staff member that led up to that color, which would reveal the reasoning
behind it. In the case of prescriptions, nurses have no insight into the reasoning of physicians when
calculating drug dosages. A strategy has been developed to overcome the problem by including
both representations of drug dosage and facilitating error detection, but it has yet to become part
of the routine procedures. Sharing interpretations of information is commonplace at the PED, but
in order to create a more resilient monitoring, ways must be found to make the reasoning
underlying interpretations more explicit while still balancing the information overload.

7.3 Anticipating: Dealing with the potential
Closely associated with monitoring is the capacity to anticipate potentially critical events. As
mentioned in section 7.2.1 above, experience is a crucial ability for identifying risks based on the
familiarity of a given situation when monitoring. Anticipating, however, requires a person to go
one step beyond by also figuring out which risk indicators to monitor in the first place. Following
the terminology of Klein et al. (2005), this requires an alert stance, always being on the lookout for
potential threats. Examples of such a stance could be observed during my case study: For
instance, a physician about to receive a critically ill patient at the main ER expressed concern
with taking the elevator, since getting stuck could mean endangering the life of the patient. One
nurse pointed out that the current emphasis on experience as a complement to the metts-p triage
system might have to do with the fact that trust for the relatively new tool is still quite low among
staff members. A healthy dose of suspicion as well as attempts to increase risk awareness such as
the “risk jars” might be possible ways to enhance this alertness, supplementing the systematic
tools for observing ill-defined risk indicators to make the process of monitoring more resilient.
Communication tools also need to be supplemented with some vigilance: I was told by a doctor-in-
training about an experience during training with a defibrillator, where he followed the
appropriate procedures and shouted “clear the bed!” before pretending to turn the power on –
however, he did not wait to actually confirm that everyone heard the warning. One person
deliberately pretended not to listen and stood still by the bed as a demonstration, and had the power been on for real, this could have led to a fatal electric shock.

The frequent double-checking of prescriptions by nurses also seem to indicate a risk aware safety culture at the PED, one nurse jokingly stating that “our job is to be a pain in the neck to the physicians”. More importantly, this risk aware behavior is appraised by physicians, following Woods’ line of thinking that resilient organizations must be prepared to sacrifice efficiency to follow up false alarms (2006). A commitment to safety is also evident from the fact that staff members do make the effort of using inappropriately designed tools for anticipating, such as the database of the Electronic MR system requiring users to scroll through a long list to find the proper keyword for an entry. By avoiding to simply place all entries under the “other” category, the staff makes sure that a working, searchable database is maintained, where particular aspects of a patient’s medical history can be highlighted to reveal potentially vital clues regarding the future state of the patient.

7.3.1 Handling maladaptive behavior

As mentioned in section 2.3.3, a central ability of a resilient organization is to successfully monitor the behavior of the organization itself on different levels to identify activities that are locally adaptive but globally maladaptive. Woods and Branlat (2010b) propose a polycentric control architecture to achieve this, where there are several interdependent control centers with partially overlapping authority and responsibilities, compelling them to dynamically balance the upholding of various sub goals. The supervisor of the PED states that the aim of the department is to avoid a strict hierarchy between different professions, believing some degree of overlap between work tasks to be beneficial for enhancing cooperation between nursing staff and physicians. A possible future step in this direction is to place doctors-in-training together with nursing staff care teams in the modules, an idea that has already been implemented at the main Acute Assessment Unit of Linköping University Hospital. Although this might lead to an increasing overlap between work tasks, the division of authority in the healthcare domain is still hardly polycentric – the physician in charge ultimately may overrule any treatment-related decisions. In practice, however, the nursing staff at the PED enjoys a relatively high degree of freedom and takes active part in discussions and decision-making processes.

Although physicians are medically responsible, the implementations of care acts are normally delegated to the nursing staff during normal day-to-day routines at the PED. However, my observation of the emergency training course revealed that the medical responsibility of physicians might sometimes entail a peculiar double-role of both expert and leader. During emergency situations, physicians are involved in hands-on treatment at the very sharp end of activities, while at the same time are required to maintain an overview over the whole care process. Although the course instructors pointed out that the ideal situation is for the physician to stand by and focus on calculating prescriptions, the physician course participants frequently got preoccupied by detailed interventions, sacrificing the oversight, and yet the discussions after each scenario made clear that they were also expected to keep track of other tasks, such as documenting and evaluating the care process. Distributing tasks more evenly across team members might reduce the risk of getting stuck in a globally maladaptive behavior.

7.3.2 Maintaining buffers

Whereas anticipating maladaptive behavior is critical during emergency situations, one of the most central issues of day-to-day work at the PED is anticipating patient load, discussed in detail
in regard to the sub goal of **having the adequate staffing** of the CSE analysis. As discussed in section 7.1, the capability to respond is very high at the department, utilizing the great flexibility and tools for generic team competencies to effectively deal with unexpected events. Anticipating the future situation at an emergency department, however, is much more difficult, an inherent problem built into the domain itself. Nevertheless, the CSE analysis revealed that certain regularities of patient load variability do exist, such as the month of March when my case study took place being known for the very high increase in children catching the respiratory syncytial virus (RSV). Although several strategies exist at the PED for adapting to patient load, there is a constant fear of a bed crunch, which in RE terms would correspond to the buffers being depleted, risking a decompensation. This meant that the primary aim during March was to reduce patient load in the first place, only receiving patients really in need of acute care. A major problem experienced by the staff is that parents of relatively healthy children tend to overestimate the severity of the situation. Many parents first contact the telephone-based nurse counseling service provided by the Swedish healthcare system, which serves to identify some of the non-critical cases and refer them to health centers. This is a difficult task however, as put by one of the nurses at the PED: “It’s like trying to envisage the *Mona Lisa* from a description over the phone”. During my case study, the supervisor of the PED in fact asked a local TV station to make a news broadcast at the department, describing the high patient load and encouraging parents to contact their local health center in the first place. This might have increased awareness of the situation at the department somewhat, but staff members at the ER still did not escape the undesirable task of sending healthier patients home directly without medical examination, balancing the tradeoff between treating patients and maintaining a sufficient bed capacity.

Moreover, despite attempts to reduce patient load, the number of patients actually in need of acute care during March was still high. This led to staff members of the PED being required to work overtime, especially over weekends when standard staffing is seen to mirror patient load trends poorly. As discussed in section 6.3.2 of the CSE analysis, this solution had consequences: Long periods of overtime will lead to increasing fatigue among staff members, inevitably sacrificing the chronic goal of maintaining an alert stance to achieve the acute goal of responding to increasing patient load. The Swedish Working Hours Act (2008:476) states that employees must have at least 11 hours of rest every 24-hour period, limiting the extent to which this temporary solution can be used. However, one physician points out that to meet increasing demands, there are occasional workarounds to the regulations: The breakpoint between 24-hour periods is flexible, meaning that it is fully legal to place all working hours at the end of one period and at the beginning of the next, in effect working double shifts. In the long run, such workarounds lead to slowly eroding margins, undermining the capacity to respond.

### 7.3.3 Shifting between response strategies

As mentioned in section 7.1.1, the adaptive capacity of the PED is tightly linked to the flexible use of communication, being more explicit when distributed across many people and longer time, otherwise relying more on shared context and common ground to allow for implicitness. Moreover, staff members are committed to being more explicit when facing more severe situations, and also have a range of ready-made emergency responses at their disposal. However, situations can escalate quickly at the PED and the crucial question is: How does the staff *anticipate* when a situation demands a shift in response strategy, and how quickly can such a shift be executed? Critical information is supposed to be entered instantly into the Electronic MR, but determining what is critical in the first place is not entirely straightforward. There is also no way for a staff
member to know beforehand that they will not be interrupted by information interference during
the computation of a task, so each reliance on internal memory and implicitness could be seen as a
small but possibly severe risk. Relying on common ground will also lead to problems when
cooperating with members from the staffs of other departments, with less understanding of the
workings of the PED. The staff members express awareness of this, likely adapting their
communicative behavior to become more explicit during cross-staff cooperation. However, a DC
perspective suggests that the ways of thinking at the PED are more firmly rooted in the local
culture of the department, with such things as metts-p colors representing patients and the “code”
used in patient binders by nursing staff probably hard to adapt to outsiders.

Furthermore, even though the ready-to-use solutions to emergency situations facilitate fast
responses, the criterions for what constitutes an emergency situation are not clear-cut, and there is
likely no way to define such criterions, instead relying on the professionalism and experience of
staff members. Even if this works, however, the staff members admit that sharing an
understanding of the severity of an emergency situation with newly arrived people, often from
different departments, is problematic. This type of understanding should be possible to achieve
through the use of subtle cues, such as shorter messages than normal to indicate higher time
pressure, as proposed by Hutchins (1995a). During emergency training courses, however,
instructors put more emphasis on always “keeping the calm” when communicating, which might
add to the confusion despite being beneficial to overall team communication.

7.4 Learning: Dealing with the factual
While the unexpected nature of acute healthcare certainly makes dealing with the potential a
difficult matter, it also complicates learning from past events, since future events might turn out
completely differently. The well-known reoccurring periods of high patient load, however, do offer
concrete improvement suggestions: Regarding the short-term time scale, a decision was made
during the course of the case study to add one nursing assistant to the standard ER staffing during
weekends and night shifts to better mirror the increasing patient load. The patient safety
developer also points out that “something must be done” regarding the hectic period next March.
Learning is closely related to the sub goal of Understanding the workings of the system described in
section 6.2 of the CSE analysis, involving the patient safety developer’s tasks of compiling the
results of risk and event analyses from the Children’s Hospital as well as the supervisor’s
measuring of various parameters of patient safety development at the PED, such as hygiene
routine adherence. The workplace meetings held by the supervisor every week serve to let staff
members influence learning at management level with sharp-end experiences, although each
meeting will involve only a fraction of the staff and typically include no physicians. The
subsequent e-mail updates propagate the new knowledge throughout the department, however
new memoranda and guidelines are usually read by staff members just prior to the first time
applying them. Learning from other departments is made possible through the monthly meetings
with supervisors, deviation coordinators and the patient safety developer, who also stresses the
importance of letting staff members working at the sharp end influence higher-level decisions. The
aim is furthermore to have deviation coordinators represent all different professions, which is why
the roles are filled by one registered nurse and one nursing assistant at the PED. The group was
also recently expanded with two physicians, hoping to encourage more frequent deviation
reporting from that group, which according to the patient safety developer tends to be low.
7.4.1 Risk and incident reporting
As discussed in the CSE analysis, many risk indicators at the PED are ill-defined, and identifying them as risks requires both experience and an alert stance, as mentioned in section 7.3. As a consequence, the pass criterion for reporting a deviation will inevitably be the subject of individual judgment, consistent with the typical situation in the healthcare domain according to Pasquini et al. (2010). Staff members undergo no particular training to identify deviations, but risk awareness is highly endorsed, both at the department itself and by the Patient Safety Unit. Healthcare being what Pasquini et al. (2010) call a domain of many microcommunities, feedback according to the authors should be quick and targeted to the relevant community members in order to be efficient. However, learning from deviation reports on both risks and incidents at the PED is associated with certain delay – the patient safety developer points out that all deviations cannot be followed up, instead focusing on the most problem-ridden main processes. After especially hectic periods, however, staff members working at the sharp end often do evaluate their day-to-day work outside the centralized deviation reporting system, following one of the key principles of Resilience Engineering by evaluating what went right and not only what went wrong. Evaluating performed actions and documenting is also stressed by instructors of the emergency training course, and each scenario ends with a session where both successes and problems are discussed by the course participants.

7.4.2 Reporting culture and the backside of experience
Overall, staff members express the opinion that the climate at the PED is one of openness – according to the supervisor, pediatric healthcare by tradition attracts individuals who are not that concerned with prestige. According to the Patient Safety Unit, deviation reporting is frequent at the Children’s Hospital with reports of risks exceeding events, seen as a sign of a proactive, risk aware culture. As mentioned in section 3.3, this is in fact the main reason why one of the Children’s Hospital departments was chosen for my case study. Furthermore, being open-minded about admitting one’s limitations is endorsed at the department, facilitating learning by sharing experiences. As discussed in section 7.2.1, personal experience is indeed a necessity for getting a “clinical eye” to successfully monitor risk indicators and is also highly appraised by staff members and the supervisor, stating that it is crucial to have “the right competence in the right place”.

This attitude clearly reflects the focus on individual operators, characteristic for the healthcare domain. One doctor-in-training at the PED meant that knowing the experience level of colleagues is important, since there is no point in asking someone with lower competence for help. Similarly, a nurse pointed out that when a treatment mistake is being made, going back to the medical record might help explain the event if the staff member signing the treatment is known to be inexperienced. This sheds light on a potential problem with the focus on individuals: The person who signs a treatment in the medical record bears sole responsibility for the correct implementation of it. According to a nurse at the PED, one usually does not administer a drug that was prepared by another colleague unless that person’s competence is fully trusted. Actually, the drug administering system of the Electronic MR has two separate buttons for “Administer” and “Sign”, indicating that signing in itself serves no communicative purpose in real-time, instead functioning as “proof” in hindsight that an action was performed by a certain individual. Despite attempts at getting away from the “shaming and blaming” culture in Swedish healthcare, it seems like the focus on individual craftsmanship still makes such thinking tempting, described by Amalberti et al. (2005) as a major obstacle against safety progress. Perhaps it is an inescapable
backside of the safety contributions of personal experience in the healthcare domain, being what Reason (2004) calls “a very personal business” (p. ii28).

7.5 Summary
The following chapter describes the Resilience Engineering analysis of the Pediatric Emergency Department, based on the analyses of the two previous chapters as well as on data which was excluded from these analyses. The department’s potential for resilience is analyzed by describing each of the four capacities responding, monitoring, anticipating and learning one by one in that order.

7.5.1 Responding
The responding capacity of the PED is excellent, facilitated by a training of generic team competences and a range of ready-to-use tools for emergency situations as well as the great flexibility stemming from the possibility to bypass regulations when necessary, tailor tangible object and adapt explicitness of communication to demands in distributedness as well as changing workload/degree of severity.

7.5.2 Monitoring
Monitoring is also flexible and supports longitudinal coordination, however tools for monitoring parameters such as patient ID and drug dosage have some weaknesses, and supply of equipment is partially monitored outside the department, leading to occasional surprises. Tools such as metts-p are useful for structuring monitoring of ill-defined parameters, but need to be supplemented with the experience of staff members to identify risks outside the pre-defined set of indicators. Experience, in turn, should be supplemented with shared reasoning between staff members, currently somewhat neglected.

7.5.3 Anticipating
Anticipating which risk indicators to look for, however, is facilitated by an alert stance and commitment to safety among the staff. Nursing staff enjoys relatively high degrees of freedom, but the control structure is in principle hierarchical with physicians having the authority, seemingly leading to some risk of globally maladaptive behaviors during emergency situations when the physicians’ problematic double-role of experts and leaders become apparent. The need to maintain buffers to handle increasing patient load is recognized, but the unexpectedness of acute healthcare makes this inherently difficult and some risky tradeoffs such as having staff working overtime are required. Furthermore, it complicates the task of anticipating when shifting between response strategies is needed, possibly making the implicitness of communication somewhat risky, should the situation suddenly escalate or if there is a need to cooperate with staff from other departments.

7.5.4 Learning
A centralized deviation handling system exists for learning, influenced by local experiences from deviation coordinators working at the sharp end. Feedback to sharp end staff members after an event is delayed, but staff members often evaluate their day-to-day work outside the deviation handling system, including also the things that went right in following the principles of Resilience Engineering. The climate at the PED is risk aware, however identifying deviations is subjective to experience. The focus on experience also lends itself to some tendencies to attribute errors to individuals, possibly an inescapable aspect of the personal characteristic of the healthcare domain in general.
8 Discussion

In this chapter, the findings from the analyses in chapters 5-7 are summarized and discussed at an abstract level together with the theoretical background from chapter 2. When stating the aims of the thesis in the introductory chapter, I asked the following questions:

- What differences between Distributed Cognition and Cognitive Systems Engineering come to light when employed to analyze resilience?
- Are the differences entirely superficial, or do they have a decisive impact on the study of safety?
- Are there any aspects of Distributed Cognition or Cognitive Systems Engineering significant to the understanding of safety that are lost in the Resilience Engineering approach?

Each of these questions will be addressed one by one in the following sections, ending with the concluding remarks of this thesis.

8.1 Differences between the research perspectives

The most apparent difference between Distributed Cognition and Cognitive Systems Engineering that the ethnographic case study illustrates is perhaps the extent to which each research approach contributed to the various aspects of the Resilience Engineering analysis. Whereas both of the former analyses shed light on the responding as well as the monitoring capacity, only the CSE analysis included information regarding the capacity of learning and neither one fully caught the aspect of anticipating – this part of the RE analysis was almost entirely based upon data excluded from the other two. This result, in turn, can be attributed to the aforementioned difference between the three research perspectives when it comes to whether to focus on the “here-and-now” aspects of an organization, or rather its attitudes towards the potential.

8.1.1 Distributed Cognition

In this respect, the Three-Level Analytical Framework of the DC perspective emphasizes the as-is cognitive system status to the most, directly targeting the very flow of representational transformations while closely detailing the coordination across various tools and social structures. Seeing that the capacity to respond concerns dealing with the actual, this is inevitably the RE term which will be described the richest by a DC analysis together with monitoring, which also deals with real-time issues of risk indicators. It should be noted, however, that the capacity of learning could in principle also be included in a DC analysis: Indeed, no less than three chapters in Hutchins’ Cognition in the Wild (1995a) are dedicated to the issue of learning. My strict adoption of the Three-Level Analytical Framework, however, meant that full focus lay on the real-time issues of the cognitive system, excluding the analysis of learning altogether.

8.1.2 Cognitive Systems Engineering

The ECOM analysis of the CSE approach that I used has a similar focus, although the indirect study of cognition as control means that the core process of the cognitive system is analyzed in terms of the control processes that are needed in order to manage it. Whereas the typical DC fashion is to closely follow the representations through the system, a CSE analysis instead attempts to identify all activities necessary for control, which might still be distant in space and time. One such activity is to build a construct by understanding the workings of the system, which is closely related to the RE capacity of learning as discussed in section 7.4, meaning that this issue is better
covered than by using the Three-Level Analytical Framework of DC. However, all control activities identified still pertain to the real-time status of the core process – less focus lies on the potential future status of the system. As mentioned in the theoretical comparison in section 2.4.4, this is to some extent covered by the CSE concept of feedforward, however only the highest control-loop of the ECOM, the targeting loop, can be said to truly correspond at least in part to the organizational capacity of anticipating in the RE sense. In comparison, an RE analysis of an organization takes no direct interest in the core process taking place at all, but rather in the safety-related activities and the attitudes toward these within the organization.

8.2 The impact on studying safety

From a Resilience Engineering standpoint, some of the differences between DC and CSE discussed in section 2.4, such as the dissimilar views on cognition, might be considered too detailed to be of relevance for the study of safety in an organization. The aforementioned differences regarding the contribution to understanding responding, monitoring, anticipating and learning, however, cannot be regarded as entirely superficial, considering that all of these capabilities are seen as equally necessary requisites for creating resilience. Missing the aspect of learning in a DC analysis should reasonably have an impact on studying safety, which suggests that the research approach by itself is less appropriate than CSE as a platform for analyzing resilience.

8.2.1 The prospect of adjusting the scope

As mentioned in section 3.5, both the DC and CSE analyses I did for this thesis are almost like “parodies”, deliberately following their respective descriptions as strictly as possible in order to enable a comparison. In principle, however, it would be possible to conduct less rigid analyses which could include other aspects of cognitive systems, such as a DC analysis covering learning as already discussed in section 8.1.1. Especially in the case of the descriptive Distributed Cognition approach, however, conducting a successful study on safety might require that general methods like the Three-Level Analytical Framework are given a more streamlined focus. That way, some of the pure curiosities observed in a DC study can be omitted to make way for a heavier emphasis on how safety is manifested across a distributed cognitive system. The examples of DC analyses in the healthcare domain given in section 3.2 demonstrate that it is fully possible with the research approach to provide important insights on safety issues. For Distributed Cognition to provide a full-fledged resilience analysis method, though, a more explicit focus on issues such as learning is needed to make sure that they will not be overlooked.

8.2.2 The missing aspect of anticipating

Regardless of the scope by which a DC or CSE analysis is applied to a study, however, the approaches are ultimately bound by the limits of their respective frameworks. Both DC and CSE analyses seem to exclude the aspect of anticipating, meaning that from a Resilience Engineering perspective, neither approach can ever account for more than part of the whole picture of a safety-critical domain. Focusing on the ability to anticipate is what distinguishes RE from the other two perspectives – while the ETTO principle or detailed accounts of coordination tools might explain how an organization solves complex issues by adapting, RE seeks to explain why such solutions might mean trouble if they make the organization too optimized to certain conditions, thereby becoming brittle in the face of new, unthought-of situations. To some extent, this idea is present in the CSE approach as well, evident in the critical attitude towards artifacts being designed for simplicity, concealing the real complexity of a system. Resilience Engineering, however, takes this line of thinking to a new level, addressing not only single artifacts or activities but the capacity of
a whole organization to self-monitor the way it is constituted, reorganizing itself if needed. In comparison to the descriptive DC and the predictive CSE approaches, RE is to the greatest extent a prescriptive approach, problematizing the findings from other analyses and pointing to which organizational capacities that needs to be strengthened in order to reinforce the potential for resilience.

8.3 Missing aspects of safety in Resilience Engineering

Having established that neither Distributed Cognition nor Cognitive Systems Engineering fully addresses all aspects of safety covered by Resilience Engineering, the remaining question is whether there is any safety-related aspect found in DC or CSE analyses that RE does not catch by its own?

8.3.1 The CSE contribution: Providing inferential power

Cognitive Systems Engineering, first of all, is basically the forerunner of Resilience Engineering as discussed in section 1.2, and although the approach retains a somewhat wider focus on cognition as control, this difference becomes negligible when adopting CSE to study a safety-critical domain. Rather than providing something new to the understanding of safety, CSE provides RE with a well-fitting analysis method, serving as a tool for gaining the missing inferential power of RE in the sense of Halverson (2002). Utilizing CSE, the abstract abilities of a resilient organization can be depicted in terms of control-loops, based upon observable data. The responding capacity has a clear connection to the CSE strategies of increasing the variety of control actions, thereby gaining better adaptability. Monitoring corresponds to updating the CSE construct with feedback (lagging indicators) as well as feedforward (leading indicators), whereas learning as mentioned before is linked to the CSE long-term aim of understanding the workings of the system, thereby building a better construct. The feedforward channels at the targeting level of the ECOM, finally, could be said to at least partially match the ability to anticipate. Although a pure CSE analysis does not cover the full range of resilience capacities, it can serve as an empirical ground providing entry points for a more thoroughgoing RE analysis problematizing the findings and further addressing the organization’s attitudes toward its current disposition.

8.3.2 The DC contribution: Bringing back the physical context

What the Cognitive Systems Engineering perspective does not bring, however, is the inclusion of context. As noted in section 2.4.3, DC and CSE both emphasize context, but in quite different ways: The CSE approach regards social context as essential to understanding the workings of a cognitive system, but context is still an abstract affair, typically not ending up in the modeling of such a system. The major difference between Distributed Cognition and the other approaches in this regard is the inclusion of the physical context of a cognitive system. In contrast to the CSE aim towards generalizing abstract patterns across multiple cognitive systems, DC depicts the specifics of tools and spatial arrangements across workplaces in great detail. The term as used in the DC perspective denotes the cultural and historical context, shaping the physical forms of representations which in turn shape the ways of thinking in that context.

The ethnographic case study illustrates how this inclusion of the physical manages to catch facilitations of cognitive tasks such as the “intelligent use of space” described in section 5.2.3, but also that it reveals how physical properties come in play when creating the potential for resilience. The capacity of responding is closely linked to the high adaptability that comes with tailoring, multimodal communication and close physical proximity between team members, as noted in
section 7.1.1, and visual re-representations of numeric values provide leading indicators to monitor risks, such as the dosage visualized by different-sized syringes in the healthcare case. Furthermore, taking historical factors into account such as the background of a particular tool design can provide important clues as to why a task is performed the way it is, or as in the particular case of the PED, why the safety-critical weight parameter on the Emergency MR is easily forgotten when it is not a part of the metts-p triage task around which the MR is shaped. In fact, the DC perspective on historical factors could in a sense be said to correspond to the otherwise missing capacity of learning, since the history of interactions with tools can explain how certain ways of thinking are learnt by the users of the tools. However, learning in the sense of DC is manifested through the forms of low-level representations, meaning that it is hard to relate to the much broader organizational learning capacity described in the RE approach.

Issues regarding physical context such as these do however bring a new dimension to the dilemma of creating the capacity to anticipate in a safety-critical organization, and therefore should be of great interest to the Resilience Engineering research approach. As discussed in section 7.3.3, the tight link between explicitness of communication and physical distributedness across space and time, providing an excellent response capacity, also means that the organization optimizes its behavior to match specific demands – as a result diminishing the ability to quickly shift response strategy, should the situation change. In the healthcare case, the explicitness of communication varied closely with the various types of physical tools for written communication, shaping the ways of thinking and actually contributing to the optimization process. The DC approach alone would not have identified such safety-related weaknesses, but it could give the RE analysis insights into potential problems with utilizing the physical context of a cognitive system.

8.3.3 The physical aspect of cognition

On a deeper level, bringing in the physical context of a cognitive system into a safety study also opens up for a more direct analysis of cognition. As noted in section 2.1.2, Hutchins’ adoption of the computational metaphor of cognition stresses the physical realization of representations, since they constitute they way in which members of a culture perceive their meaning (1995a). The DC analysis in this thesis provided examples of this: For instance, the (physical) metts-p colors used to categorize patients are also used in communication to refer directly to the patients represented by the colors, shaping staff members’ ways of thinking, and the (physical) tool used only by nursing staff lead to a certain “code” evolving among these staff members, meaningful only to them. Such findings could be argued to be too detailed to be of relevance in a safety study, but the focus on anticipating in the Resilience Engineering analysis revealed their value: In the RE analysis, it was argued that such “codes” could make the organization more brittle when having to cooperate with staff from other departments (another “culture”, as it were), people who do not share an understanding of the conventions. Again, the DC approach would not have identified such weaknesses by itself, but through the lenses of the problematizing RE perspective, the detailed descriptions of how ways of thinking function as adaptation strategies become valuable insights into the inherent risk of a reduced ability to anticipate future dangers. In that sense, the differing view on cognition in DC compared to CSE does have an impact on the study of safety after all, contributing to the analysis of resilience in a way which the CSE approach might overlook.

It should be noted that although a CSE analysis might typically leave out contextual details, the ECOM as described by Hollnagel and Woods does include the low-level tracking loop, pertaining to routine operations by individuals carried out in an unattended manner (2005). Such a low-level
control loop might include context-specific coagency between artifacts in the physical environment and individuals, bringing a somewhat more direct focus on the issue of cognition in the cognitive system. However it is not entirely clear how the “unattended” activities at the tracking level are supposed to be studied. As described in the introduction to chapter 6, I left out the tracking level in the CSE analysis of the thesis, deeming it both too fine-grained to be relevant in understanding the joint cognitive system as a whole, but also impractical to analyze successfully in the larger context of a case study. I also mentioned in section 2.2.4 that the tracking level was seen as too detailed to be included in an earlier analysis of organizational capacities using ECOM (Gauthereau & Hollnagel, 2005). Seeing that the CSE approach in general displays disinterest in the specifics of low-level cognitive processes, it could be argued that the tracking loop was never intended to be included in any actual analysis using ECOM at all, rather being there to give a sense of completeness to the model.

With the Distributed Cognition perspective, however, it is demonstrably possible to discover relevant low-level aspects of cognition, which could be said to correspond to the somewhat obscure tracking level of ECOM. Interestingly, the DC principle of observing the readily available physical representations in the environment lends itself to a concrete way of studying cognition, arguably more productive than trying to deduce what goes on inside the heads of individuals. Adopting the focus on the physical from the DC approach in a combined CSE/RE framework might actually bring another layer of inferential power to the blend: How the potential for resilience is obtained can be explained through an analysis of the means of control, and how the means of control are obtained can in turn be explained through an analysis of how cognition is distributed in the physical context.

8.3.4 Impact on future research directions
This kind of framework could make it possible to find important links between detailed cognitive processes and more abstract capacities at an organizational level, but there is also a risk that such a multi-layered approach could turn out to be unmanageable. As expressed by the founders of CSE, one must be cautious not to “become lost in the detail of particular settings at particular points in time with particular technological objects.” (Woods & Hollnagel, 2006a, p. 4) Avoiding this trap in order to retain the predictive/prescriptive qualities of CSE/RE will certainly be the main challenge of incorporating DC to the approach. New questions will also be raised, such as the proper size of an organization or cognitive system where this type of approach could be fruitful, and which research methods that would be appropriate to apply (for instance, writing field notes might have to be complemented with more fine-grained methods such as video recordings in order to fully include details in the physical context of a cognitive system, and even more so to catch aspects of embodied cognition that were given relatively little room in the DC analysis of this thesis).

The prospect of a research approach on resilience mixing concepts from both CSE and DC might also warrant a reminder: The proponents of Resilience Engineering have made a point not to connect the perspective to any specific analysis method in particular (Hollnagel, Nemeth, & Dekker, 2008). If this position is maintained, a method for directly studying resilience might not be the way to go at all, rather keeping RE in its current role as an abstract viewpoint on safety, influencing other methods with stronger inferential power. However, such a development will entail that the benefits of including DC discussed in this section risk remaining absent from the RE approach.
8.4 Concluding remarks

In this thesis, I have compared the three research approaches Resilience Engineering, Cognitive Systems Engineering and Distributed Cognition, both through a literature review and by using all three in an ethnographic case study, with the purpose of gaining a better understanding of what the latter two approaches can contribute to the former. The findings suggest that both DC and CSE can provide knowledge about how an organization responds to current demands and monitors critical risk indicators. The focus on representational transformations in DC brings especially rich descriptions of the “here-and-now” of an organization, while the more indirect study of control processes in CSE lends itself better to also understand learning. However, neither approach covers the attitudes towards potential future demands in an organization completely, meaning that the capacity to anticipate is not fully addressed.

Regardless, the inferential power of Resilience Engineering could be increased by the inclusion of the Cognitive Systems Engineering perspective, providing a seemingly well-fitting analysis method serving as an empirical ground for a more thoroughgoing RE analysis. The abstracted depiction of an organization in CSE will leave out potentially vital aspects of the physical context, however, which need to be addressed using another framework such as the one provided by Distributed Cognition. On the other hand, the focus on low-level cognitive processes of the descriptive DC approach might lead to getting too occupied with specific details. The challenge lies in finding a way to integrate the aspects of DC relevant to safety into a CSE/RE framework.

That said, Distributed Cognition does not only go into greater detail than Cognitive Systems Engineering when studying the physical forms of representations, but also widens the analysis further by inferring the cultural and historical factors which shape these forms. Seeing that these two levels are intertwined, the details cannot simply be left out – finding a way to embed those details into the high-level Resilience Engineering approach might be the next important step on the road to creating a new way of thinking about safety.
References


