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Work and Technology Use in Centers of Coordination

reflections on the relationship between
situated practice and artifact design

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ABSTRACT

The research problem explored in this thesis is how technology and work practice are related in coordinative situations (collocated and over distance). Further, the problem of how this kind of research results can be transformed and used in the development of new technology is discussed. Air Traffic Control and Emergency Call Centers are the two domains where the complex process of coordination in a time and safety critical setting has been studied. The methodological approach taken in the field studies is ethnographic, a qualitative method with a descriptive outcome.

Air traffic controllers focus on keeping the airspace organized so that the aircraft are separated at all times, as well as are given an economic route by e.g. slowing down so that they do not have to wait in the air for traffic ahead. In order to manage the control of the national airspace, it is divided into geographical sectors each of which is controlled by 1-2 controllers. The aircraft cross many sectors during one flight and each time they cross a sector border there is a handover of responsibility between the controllers. The controllers have a large number of tools that they orchestrate in order to maintain control and keep records of the orders given to the plots. The situation in one sector has therefore been locally stored at their work position. It is shown in the thesis how the social interaction and the technology support are ordered to broadcast the locally stored information.

Emergency call centers at SOS Alarm are in contrast to the ATC centers fully computerized. The operators use CoordCom, a system that is currently in the process of being renewed. When a telephone call to the emergency number 112 is received in one of the 20 local centers in Sweden, a receiving operator initiates the case by interviewing the caller in order to categorize the incident. Often, an incident consists of a number of conditions that together make an emergency. It is shown that accountability of decisions and local knowledge of the center's responsibility area are two important parts of coordination at SOS Alarm.

A question that has been of interest during the studies is what possibilities ethnographic observations provide when used as a starting point in a design project. The final study provided a description of how the ethnographic material from the emergency call center study was explored and transformed in order to create concrete functionality and design.

The thesis contributes with examples from the workplace studies of how people interact with each other through the technology and how skills, local knowledge and professional concerns shape the interaction. It also contributes with reflections on how descriptions and experiences of work practice and technology use in the field can serve as a foundation in shaping and designing new ideas and new functionality for future systems.

The papers included in this thesis shows results on four issues in relation to coordination and technology:

- Coordinative work practice and implications in using video/audio in a distributed setting
- Support for accountability in decision-making in a distributed setting
- The role of local knowledge and combined expertise in a local collocated center
- The transformation of ethnographic observations in the design process

The thesis also shows the importance of a further definition of the dichotomy of collocated and distributed work in order to inform technology. An analysis of the dichotomy based on the field study results is presented in the thesis.

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and above all:
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1. Introduction

The object of analysis in this thesis can in its simplest form be described as the *use of artifacts* as means for *collaboration* (collocated or distributed) in a *work* context. The purpose of studying this issue is to consider ways in which collaboration can be better supported in new design. This purpose implies not only questions about what is going on at workplaces, but also questions about method; what kind of data seems to be useful for the sake of making new design out of the findings made at the workplace. The approach taken is descriptive; ethnography is a post-modern research approach that originally was used to describe how members of a certain context construct and interpret their culture. The domain in which the workplace studies have been conducted is centers of coordination or control rooms; in this case air traffic control and emergency dispatch. These places are highly coordinative and they have two decisive properties that affect and shape the work situation; the time- and safety criticalness.

Many of the issues described in this thesis are in their nature *transforming*. The workplaces described are continuously transforming and changing; new staff members are added, practice changes due to new regulations and so on. The actual work is a process of managing transformation; the order in the airspace is constantly transforming for the air traffic controllers and the safety of citizens is disrupted by accidents that the emergency dispatchers try to solve. Technological possibilities and resources are also constantly transforming and developing. The thesis elements, work practice and interaction with artifacts in centers of coordination; possibilities for support in collocated/distributed collaboration, add up to descriptions of transformation of different kinds; the purpose of this thesis is to present reflections on the relationship between these elements.

This research is related to the research field Computer Supported Cooperative Work (CSCW). This field poses questions concerning the possibilities and constraints of technology within a social context. It is in turn part of a larger research area, Human Computer Interaction (HCI) that is generally concerned with describing and evaluating technology and developing solutions for a more human oriented technology, see e.g. Preece (1994). These two areas are multidisciplinary; CSCW in particular has had strong elements of sociological and psychological research issues as well as computer science.

Problem definition

The research problem explored in this thesis is *how technology and work practice are related in coordinative situations (collocated and at distance) at centers of coordination*. Further on; *how this kind of research results can be transformed and used in the development of new technology*. The main concern in this thesis is situated practice and technology use in a center of coordination the second concern is the use of field data as a resource for design. Beginning with the former I would like to give an overview of the perspective taken upon these issues and some assumptions made when investigating this field.

Traditionally the sociological influence in CSCW has placed work practice and the workplace in the center of interest. One motivation for this has been to make the professional skills of workers visible (Suchman, 1995). Another reason has been to study how work practice is socially ordered and distributed with the purpose of informing new design. My interests are related to the Swedish research field Work and Technology (Yrkeskunnande och teknik) that puts a focus on the profound role that professional skills and experience have in the interaction with technology and the ordering of one's work (see e.g. Göranzon, 1990; Perby, 1995). Although skills and thorough knowledge of an activity can be found elsewhere than in a work context, the explicit orientation towards common activity goals in an organization makes it a useful place to study the role of technology in relation to experienced use.

The work in centers of coordination, such as for example a paper mill control room, is in its character a constant management of a continuously transforming work object that is usually handled at a distance in the control room. In the case of air traffic control and emergency dispatch, the object is much further detached than in a plant; there are no means through which the controllers and operators can physically move the aircraft or arrange for the citizens' safety. In a paper mill, the machines can be stopped but an aircraft cannot be steered from the control tower. The controllers and operators can thus not physically see or manipulate the object of their work but have to rely on information exchange with respectively the pilots and the paramedics. They have a great need for obtaining and providing updates to each other of the constantly transforming state in their responsibility areas.

Many studies have shown that professionals in centers of coordination and other highly coordinative and collocated settings, develop a number of methods to coordinate information and work with as little effort as possible. The subtle use of body language and manipulation of common tools is often enough for skilled controllers and operators to coordinate. But work in these settings (and in general) is to an increasing extent becoming distributed and an important background to the thesis question is how the lessons we learn from a collocated setting can be used to inform a distributed setting. Face-to-face coordination is obviously not free of problems and misunderstandings, but, compared to a distributed setting, it generally takes less effort to coordinate in such a setting and it is much more flexible and easily adjusted to the situation than the opposite. Seeing when your colleague is free or not, rather than having to call or walk over when you have a question, is a simple example of such collocated efficient coordination.

A work setting is an arena where the common goal makes it necessary to coordinate and where actors to a large extent depend on tools as coordinative mediators (i.e. notes, PM's, documentation, orders, and forms). In the thesis I will discuss how social mechanisms are inscribed in different artifacts and how a competent member interprets different objects as resources for social interaction. I make a distinction between:

- cooperation: working for a common benefit
- collaboration: working jointly
- coordination: working interdependently, adjusting to the immediate work of others

Coordination is thus not necessarily when explicitly communicating with others but it also includes individual work that is consciously adjusted to others' work.

Summing up the context to my research problem: work settings in general and centers of coordination in particular provide the kind of orientation towards a common goal that calls for coordination; a constant ordering of work in such a way that it makes sense and is useful to others. Whether this constant ordering of work is collocated or distributed makes a difference, the question is how and what functions and tools that are needed to support the varying conditions.

Computer Supported Cooperative Work – background

The multidisciplinary field of CSCW includes rather different research interests. One such interest is for example computer systems that support coordination, a more technologically oriented perspective. This research is concerned with network protocols, algorithms, mobile technology and other technical solutions that enable people to share information. Another background is an interest in design for groups. More and more, the idea of one user – one computer is replaced with a view of users in interaction with others and the computer as the medium (Bødker, 1991). Typical issues from this perspective are evaluation and description of the use of different systems, for example chats, technology for the home, haptic interfaces and so on (Grinter and Eldridge, 2003; Ullmer et al., 2005). A third kind of research interest in CSCW concerns the complex skills that professionals have and how they deal with tools and technology for coordinative purposes. Often, this interest produces studies of the current situation at different organizations and some implications for a new design. These studies are usually referred to as workplace studies (Luff et al., 2000). The research presented here is mainly in line with the last path.

The research area was established in 1986, when a number of researchers with sociological and anthropological background together with people from the area of human computer interaction formulated a set of concerns. First, it seemed that tools aiming for collaboration, so called groupware, did not work very well, they often were abandoned or worked around by the users. Researchers with a non-technical background became interested in exploring social interaction at work in order to inform the new system design. They also became interested in reformulating traditional human-computer interaction research methods. They argued that computer use and the application of computers within an activity should not be considered as an isolated phenomenon; they are a part of an activity that is intrinsically produced amongst the whole work group. They started to suggest the workplace rather than the computer programs as the unit of analysis.

Of course, Computer Supported Cooperative Work is a research topic that has followed in the trace of the development of computer use (Baecker, 1993). From the beginning with the main idea to enhance groupware it has developed into an area more emphasizing group activities (Bannon and Schmidt, 1991). The "Computer Supported" part of the research field can be understood in much wider terms and does not necessarily have to involve what is traditionally considered as computers. The use of other tools may as well be helpful in informing us how tools mediate cooperation and what designs that would be useful. Another assumption is that we do not know so much how tool-mediated cooperative work is carried out. The "Cooperative Work" part of CSCW has been influenced by different sociological theories. One issue that is considered important by many CSCW researchers is to study cooperative work in its natural setting, at the place that it occurs. Bannon and Schmidt write that CSCW is:

> "…an endeavor to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies." (Bannon and Schmidt, 1989)

Designing for social meetings is a challenge within the CSCW area (Grudin, 1988). The issue stems from the assumption that in most work contexts, activities are to a varying extent socially oriented. Collocation to a large extent supports and facilitates collaborative work and social intentions, even though we have several tools to support coordination at a distance (e-mail, fax, etc). Managing coordinative work at a distance is more complicated. One idea for supporting distributed social interaction has been to mimic collocation by having a video link (Bly et al., 1993; Dourish et al., 1996; Dourish and Bellotti, 1992; Gaver et al., 1993; Gaver, 1992; Heath and Luff, 1992b; Mantei et al., 1991; Normark, 2004). That research in turn presented new challenging questions.

As has been discussed from several angles (see e.g. Winograd, 1996)); why do groupware fail? Or, approaching the problem from another angle; what properties makes face-to-face coordination more efficient? Further, consequently and one of the aims of this thesis; how can we transform and make use of this insights in the design of coordinative tools?

Overview of studies

The five studies that constitute this thesis are focused on two kinds of workplaces; air traffic control and emergency dispatch. The first study was initiated in 1998 with the aim of exploring work practice and technology use at the Danish air traffic control center at Copenhagen Airport (Kastrup). The field studies and data collection were made by me and Johan Berndtsson in 98-99. The center was at that time not fully computerized, but a system was under development and we made a study visit to the Eurocontrol test center in Bretigny while the new system was tested. Copenhagen airport is a hub where many people change flights. It also contains the area control of all Danish airspace. Following up on the Copenhagen study (study 1) I performed a shorter comparative study of Shannon airport in Limerick (study 2). Shannon has a completely different kind of air traffic; a lot of overflights that are heading to, or coming from, northern America and the airport has much less traffic than Copenhagen's.

The second field study domain was SOS Alarm emergency call centers in Sweden. The company SOS Alarm AB is responsible for answering the phone calls made to the emergency number 112. The 20 centers covering the country work as communication centers for the ambulance, the rescue service and the police. SOS has the responsibility to dispatch and monitor ambulances (some regions have local ambulance dispatchers belonging to other companies). The study of emergency dispatch was done in three separate studies; one in collaboration with Mårten Pettersson and Jenny Lundberg at Blekinge Institute of Technology; focusing on the Malmö SOS center which was a part of the SOS Alarm's new development project (study 3). The second field study at the Stockholm center was done by myself, whereas the analysis of the results was done partly in collaboration with Dave Randall (study 4). Finally, the design project was done in collaboration with Lucien Bokouka as part of his Master's project (study 5). In that study we used the ethnographic data to develop a prototype based on the findings in the field studies.

Thesis outline

The second chapter presents the methodological approach I have taken in the different studies and gives a theoretical background to the method. The third chapter introduces workplace studies in general and studies of centers of coordination in particular; it also introduces some of the social mechanisms that constitute work. The fourth chapter presents the studies of air traffic control and the result of them; it also gives a summary of the two ATC papers. The fifth chapter does the same concerning the emergency dispatch study at SOS Alarm as well as compares the two settings. The sixth chapter describes the design project in the fourth study. The seventh chapter discusses and concludes the studies.

Articles

The papers included in this thesis are:

Berndtsson, J., & Normark, M. (1999). *The coordinative functions of flight strips: Air traffic control revisited.* Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work, Phoenix, Arizona, USA.

Normark, M. (2004). *Open audio/video links as means for coordination - two case studie*s. Proceedings of the Thirty-Seventh Annual Hawaii International Conference on System Sciences, Big Island, Hawaii, USA.,

Normark, M. (2002). *Sense-making of an emergency call - possibilities and constraints of a computerized case file.* Proceedings of the Second Nordic Conference on Human-Computer Interaction, NordiCHI 02, Aarhus, Denmark

Normark, M., & Randall, D. (2005). *Local expertise at an emergency call centre*. In the proceedings of the European conference on computer-supported cooperative work, ECSCW´05, Paris, France.

Normark M (2005). *Transforming field observations into functions - on the use of an ethnographic study in the design process.* Submitted to the Journal of Interacting with computers.

2. Research approach

A fundamental contribution of this thesis is to discuss what happens in collocated collaboration; what role tools have in this collaboration; and how and why the tools that are used for distance coordination work. This thesis takes on a descriptive ethnographic approach, the unit of analysis being *practice* and how coordination and technology are applied within it. An assumption is that understanding professional skills and practice in a certain context is a prerequisite for being able to suggest a support for it.

A discussion of the understanding of practice begins this chapter. The next section describes ethnography as a method and ethnomethodology as the theoretical perspective influencing my studies. The chapter is finished with a description of the method that has been applied in the studies, what kind of data I have collected and what consequences this choice of method has had.

Professional skills and practice

Individual skills

A fundamental part of developing skills is getting *experience* within the domain in question. Experiences are not only first hand but can also be developed through talking about events in a group; this kind of talk is sometimes labeled war stories (see e.g. Orr, 1996). Experience helps people identify and classify different occurrences within the domain, which in turn helps them to decide what actions to take. Also, skills do not only mean intellectual understanding and interpretation of the domain but also so called *tacit knowledge* (Polyani, 1967). Tacit knowledge is experience that makes one inclined to know what to do without being able to articulate exactly why or how. It is the kind of knowledge that makes a doctor suspect a problem with a patient even though s/he cannot articulate the exact reasons, or that makes the paper mill worker decide that the pulp is ready for the next process step by touching it (Goodwin, 1997; Perby, 1995). It is important that systems supporting skills allow for this kind of contact with the work object in question.

Skills are also embodied (Dourish, 2001). A typical example of embodied knowledge is the skills of cycling; how one knows when to move one's weight around to adjust the balance; how to judge the suitable speed and turn the handlebars in the right angles and so on. But embodied knowledge does not have to be explicitly physical, consider for example how long time it takes for your body to learn (or rather unlearn) if you change your cutlery drawer or when you move to another apartment where the light switches are placed differently than you are used to. The body's understanding of an activity transforms more slowly than the mind's.

It has been established through a number of studies, see e.g. Heath and Luff (1991) or Bowers et al. (1995), that collocated work consists of an intrinsic weave of activities that make use of the common room in order to accomplish interaction.

Skills in the organizational setting

In order for any activity involving more than one person to work, we need to orient our actions toward each other. The more we are familiar with the activity in question, the less we have to rely on explicit talk, and instead we manage through unobtrusive cues, based on routines and understanding of each other's concerns. Knowing that others are interested in our part of the work, we also develop tools and methods to tell others what we are doing. Knowledge and action are produced locally, situatedly within a context. It is a continuous work on sharing and dividing labor. It means that any attempt to create a formal chart of work will reflect only one picture of the multitude of possibilities in which that work is done. When describing work from the perspective of a product or service that moves around in an organization, the actual production is disregarded and the complex coordination work that makes it move on is still clouded. If the working division of labor is not described, new design may hinder or destroy the common performance of work. The term ecological is used to describe the practical, ongoing, division of labor. Calvey et al. (1997) write:

> "A small set of viewpoints emerged; - the setting of the work (ecology), the social context of the work (flow of work) and the practical organisation of the work (ecological) taking place; - each presenting a particular focus on the social organisation of work activities and chosen in order to highlight relevant aspects of the sociality of work. " (section 5)

The main point is that people adjust to the situation at hand. If the secretary is busy, someone else will answer the telephone, even if it is not part of his or her formal job description. If the schedule tells someone to do a print job and the printer is broken, s/he can adjust to the situation and help somewhere else where it is needed (Bowers et al., 1995). This continuous adjustment to the situation at hand is important when designing for coordination. The flexible adjustment to situated action compared with the rigidness of a formal chart is the reason for studying the setting from the inside.

Workplace studies and descriptive approach

> ”insofar as actions are always situated in particular social and physical circumstances, the situation is crucial to action's interpretation.”
> ”The aim /…/ is not to produce formal models of knowledge and action, but to explore the relation of knowledge and action to the particular circumstances in which knowing and acting invariably occur.” (p 179)
> (Suchman, 1987)

Drawing on the perspectives that are set out in this chapter (the notions of skills, practices and collaboration) it is in consequence difficult to understand and get a comprehensive picture of professional practices anywhere else than where they normally occur. In other words; without seeing the informants in their work setting, it is hard to be able to understand the activity. And understanding the activity with all influential elements (such as how tacit knowledge and experience become a part of the job) is, arguably, essential for designing a new system. A general problem of HCI is to make design more use oriented. A conclusion is that many new programs and solutions fail because of their unsuitable design for the users. If one agrees that work is essentially socially organized, it becomes obvious that we must learn more about how technology and tools are used in general and for human to human interaction in particular. There are many rational descriptions of work that often serve as a foundation for design. However, the formal description often lacks an important understanding of the work practice that is going on. How can we learn more about how technology is used in everyday work? This is where the workplace studies come in.

Ethnography and ethnomethodology

> ”What the approach here at least offers is one way of throwing light on what kinds of flexibility are needed, what kind of technological support is appropriate, in what kinds of work: in a word, reappraising the distinction between the system and the user.” (p 143, Hughes et al., 1992)

In CSCW the ethnographic method is mainly used for the focused purpose of doing studies of work. The method was adopted from sociology and anthropology, where it from the beginning was used to study non-western cultures. By looking at complex work situations (e.g. control room work), ethnographers in CSCW try to understand how collaboration is performed *in situ* and how different artifacts in the environments affect and enable coordination. Two main reasons for using ethnography in these areas are to survey the conditions of a specific kind of work and to document the skills and practices of the people working in a certain profession. Another reason is to capture everyday, taken-for-granted cultural assumptions that shape activities. (See also Anderson, 1994; Bannon, 2000; Rogers and Bellotti, 1997; Shapiro, 1994). As the word 'ethnography' implies[1]; the outcome is an extensive written text. Analyzing the work from the standpoint of coordination is usually a part of the research.

By spending time in the workplace, ethnographers try to understand the skills of a certain profession by interacting with the professionals and trying to observe and uncover the hidden practices of the work. A special interest is often the discrepancy between how people think that they do things and how they really do them. Research has shown that it is difficult for us to estimate time and remember in detail how we do things. In order to understand and be able to analyze the skills and practices in connection to a certain setting, the ethnographer collects descriptions, impressions, stories, pictures, cases, history, drawings, and all the information that one can get in order to understand how the practitioners work.

The use of ethnography as a method is sometimes related to ethnomethodology in CSCW, basically because of the interest in how things are carried out in everyday life. Ethnomethodology is a theoretical perspective in the sense that it attempts to describe how social life is organized. However, since the interest concerns life *in practice* and not in theory, ethnomethodologists usually do not call their perspective a theory. The term ethnomethodology was coined when Harold Garfinkel wrote his book Studies in Ethnomethodology 1967 (Garfinkel, 1967). The perspective assumed that social order is always maintained but takes different forms in different settings; the question is rather *how* than *why* we interact. The main question in ethnomethodology is then; how is it possible for us to make ourselves understood? What methods or cues do we use to achieve social interaction? When do we fail to achieve understanding? Alain Coulon describes ethnomethodology:

> "The scientific project of ethnomethodology is to analyze the methods, or the procedures, that people use for conducting the different affairs that they accomplish in their daily lives./…/The "methodology" is used by the members of a society or of a social group in a banal but ingenious way to live together; these ethnomethods constitute the corpus of ethnomethodological research." (Coulon, 1995)

Ethnomethodology focuses on what is important for the continuous construction of social interaction in a given setting. In ethnomethodology it is assumed that social relations are constructed and interpreted in the same moment as they occur. Since we are continuously interpreting our environment, it is interesting to try to understand how humans make sense of the context we are in. Coulon writes:

> "The relation between actor and situation is not stable and unchanging, produced by cultural contents or rules; it is produced by processes of interpretation." (Coulon, 1995)

Trying to understand how interaction is possible and how we make ourselves understood is the core of ethnomethodology. What methods do we use to give others cues about our intentions and feelings, etc.? Garfinkel put forward the question of "What to do next?" as an area of interest in social interaction. What "signs" do we react upon that in turn trigger us to act?

Instead of trying to abstract mechanisms of social behavior,

[1] **Ethno**: people, cultural group; -**graphy**: writing

ethnomethodologists' focus on situated practice. The expression 'community of practice' (Lave, 1991) is used to describe a specific community that recognizes specific methods, practices, and skills, for example horse riders or physicians or chefs. It can, of course, be considered both at a detailed level, as certain professionals and at a general level, like people living in the western part of the world. The competent member is a person who is recognized by others in a community as such. In strict ethnomethodological sense a competent member is someone who can pass as a member of the community. Thus, it has less to do with the formal competence and more with the capability to perform as a member. The focus on competent members, however, is to find out the meaning that is derived from a certain act, from within, and is unrecognizable to people outside of the community. A nod, for example, may mean "hello", or "go ahead", or as seen amongst air traffic controllers; "I have recognized that particular complexity and I'm taking care of it". How does a competent member make sense of the signals, cues, and signs that are available in the setting? What is of importance, and what is filtered away? Suchman (1995) writes:

> "Making sense and use of representations of some aspects of the social world involves our own positioning in relation to what we are seeing as much as any meaning inherent in the images themselves." (p 63)

Every-day tasks that are performed by a qualified member in a certain community of practice are often performed in such a way that they are visible and rational (accountable) for other members. We are making accounts to explain and help others maintain order through implicit or explicit explanations. Coloun writes

> "To say that the social world is accountable means that it is describable, intelligible, reportable, and analyzable. All of these features are revealed in the practical actions of the people. The world is not given once and for all, it is constituted in our practical accomplishments. " (Coulon, 1995, p. 25)

The physical world is constantly manipulated in order to display social intent, for example by leaving ones jacket on the chair while taking coffee. But the digital world is often more rigid and not so easy to manipulate. An interesting thought therefore is how accountability of actions can be supported in a digital context. Paper B gives an example of that further on in the thesis.

Data collection

Field studies in Air Traffic control (study 1 and 2)

The fifteen months long CATCH (Cooperation in Air Traffic Control – Copenhagen) project was part of the European interdisciplinary research network COTCOS (Cooperative Technologies for Complex Work Settings), which was funded by the European Community (D.G. XII) under the TMR (Training and Mobility of Researchers) program. I and Johan Berndtsson carried out the fieldwork at Copenhagen Air Traffic Control Center.

The study was an ethnographic field study, primarily consisting of informal interviews and participatory observations. About 20 interviews were conducted, with several different groups involved in air traffic control work at Copenhagen Airport, e.g. controllers, supervisors, assistants, and technicians. These interviews were recorded on audiotape. We also had the opportunity to talk to some Swedish en route controllers, from Malmö and Stockholm ACC.

Informal interviewing was chosen mainly because it offers a significant benefit compared to more structured interview techniques in that very few assumptions regarding *what* is important in the work studied are made at an early stage. By discussing with, rather than interviewing, the informant about his or her work, the idea is that the researcher will learn what aspects of the work that are important, and therefore need further inquiry. By using a few very general questions, such as 'what does an air traffic controller do?', and 'what constitutes a good controller?' we 'steered' the interviews into topics of interest. Of course, the degree of detail in the questions increased with our knowledge about the domain. We also tried to keep the number of interviews per day to two or less, to ensure that they were analyzed as soon as possible, both to avoid piling work and thus forgetting much about the interview, and to be prepared with complementary questions for the following interviews. Beside these interviews we also had numerous spontaneous discussions with controllers, assistants and supervisors during our studies at Copenhagen airport.

The interviews were generally followed by participant observation sessions lasting between one and three hours each. During a majority of the observation sessions the informant was asked to continuously tell the researchers what s/he is doing during her/his actual work. Many of these initial observations have thus been conducted with a high level of interaction between the researchers and the informants.

Most of our studies were conducted in the Approach control (the sector concerned with inbound and outbound traffic to the airport, before or after the tower, that in turn handles traffic on the runways). There are two major reasons for this. First, we wanted to study coordination between geographically distributed actors. In the Approach, the controllers are constantly coordinating their activities with the adjacent sectors (be they Danish or Swedish), as well as the tower. Both are geographically separated from the Approach control, as opposed to studying en route controlling between adjacent sectors where controllers are often positioned close to each other. Second, the approach controllers handle a large amount of traffic within a rather small volume of airspace. This fact increases the effects of the time-critical aspects of air traffic control work, and therefore also the need for effective coordination.

In order to capture some of the details of the work with these artifacts, we also used video camera recordings for several of our observations. Video recording in a quite dark and crowded area like an air traffic control center is quite difficult. We experienced some problems with camera angles, and different angles proved to be useful in different situations. Due to the layout of the control room the alternatives for placing the camera were quite limited. We also had some problems with the sound, but we largely solved this by either placing the camera close to one of the loudspeakers playing the communication between the pilots and the controller, or by holding a handset playing the same communication close to the camera microphone.

To analyze the collected data we indexed and wrote summaries of the interviews and videotapes. We also transcribed sections that were of central importance to our project. Complementary questions from interviews and observations were handled through repeated visits, but also through e-mail, fax and telephone communication with some of the air traffic controllers. The data were also discussed with researchers studying air traffic control work in other control centers around the world.

In order to learn more about the future development of air traffic control technology we have also visited the Eurocontrol[2] test center in Bretigny to see a part of a large simulation with Swedish and Danish controllers testing a version of the future system (Eriksen and Harvey, 1999).

The shorter study at Shannon ATC centre was done by myself as a part of a larger study done by the Interaction Design Centre. I have mainly done participatory observations, taking notes of the events I have seen and what I have discussed with the controllers. Later on in the study I did some informal interviews, which I took notes of. In this study, it suited me better to take notes, since the time was very limited; notes are more easily accessible than tape recordings. I have also had informal discussions with the controllers, the watch managers and other involved at the ATC Centre in Shannon during breaks and lunches.

Field studies at SOS Alarm AB (study 3 and 4)

The SOS Alarm research project was initiated by the Work Practice Laboratory at Blekinge Institute of Technology in Ronneby and SOS Alarm. The project aimed at finding out how the operators use the technology to perform their tasks and how it could be supported in the future.

My field studies began in June 2000 at the Malmö SOS center. Together with Jenny Lundberg and Mårten Pettersson from Ronneby I continued the study until November. I mainly made observations in Malmö and Stockholm, while Jenny and Mårten mainly made observations at the Växjö SOS center. Since I live in Stockholm and had to travel to Malmö, I usually went there for concentrated periods of 1-2 whole days, about 15 times.

During the project we went for several study visits besides being at the different centers. I took part in the visits to Jönköping, Växjö and Borås. Borås has a special operator position that is really a part of the Gothenburg center. This one operator that works in Borås is there to cooperate with the fire rescue department for the east part of the Gothenburg responsibility area. Another study visit was to the Rosersberg Rescue Center located in a suburb of Stockholm, where we took part during a day when new SOS Alarm operators where educated. Further, we went to study the computer systems at other kinds of centers, namely the Øresund Bridge and the Police headquarters in Malmö.

We held two workshops, one in Malmö where we discussed problems of today and ideas for the future together with the operators, and one in Växjö were we

2 Eurocontrol is a European organization doing research and development to improve air traffic management in Europe. Visit Eurocontrol on the WWW, http://www.eurocontrol.fr, or http://www.eurocontrol.be

discussed possible new interfaces and functionality for a new way of performing the work in-between the centers. We were also a part of the reference group that SOS Alarm head quarters had put together for the first stages of the process of developing a new support system. The project resulted in a report with four parts, (Helgeson et al., 2000) that were delivered to the SOS Alarm. During the spring of 2001 I continued my field studies at the Stockholm SOS Center until the summer, but with less frequent observations than earlier (about 7 visits).

The method I used in my studies was ethnography. Basically, ethnography is used as a method to understand how an activity is performed in a certain setting, and the outcome is a written account. I have already discussed some of the fundamental assumptions behind ethnography in the theoretical part so I will not explain the method here in detail again but describe what I did in my field studies.

The main data collection method that I used was extensive notes, but I have also taken photographs and collected printed information. At a few occasions we made video recordings. In one longer case, the childbirth case that is presented in this thesis, I got access to the transcripts of the recorded conversation between the operators, the paramedics and others. A shift leader extracted the tape from the SOS own recordings and it was time-consuming work since the calls are not tagged on the tape.

The SOS Alarm setting is difficult to study for two reasons; one is that secrecy agreements put special demands on the recording possibilities and another is that there are (for my research interest) very many sources to take account of; talk in the room, conversation with different rescue services through telephone, radio etc. and also work and coordination through the networked CoordCom system. An utopian data collection method would have been to collect a synchronized version of these three parts.

Recordings also to some extent presented an ethical problem for me; how would the emergency callers feel if they knew that their emergencies were recorded and used for research at a university? Although this has been done before, I personally felt it to be somewhat problematic. Because of my focus not being specifically on the conversation, and the problems that surrounded other data recording techniques, I decided to mainly use notes as data for analysis.

Design work in the EmCoord project (study 5)

The design project presented in paper 5 was set up as a Master's thesis project in Computer Science. The aim was to try to use and transform the ethnographic observations and reflections into a suitable basis for design and finally a working prototype. Since only mainly two of us worked with the project, the roles were overlapping. The original ethnography was made by the author, the design was made together with the master student Lucien Bokouka, and the final programming was made by Lucien. An initial common study visit was made to the emergency dispatch room which gave an initial common ground of what kind of setting we were designing for. We wanted to examine whether the ethnographic material in itself could be transformed into a design. In our explorative attempt we used seven steps.

Finding the process to support

This step was inspired by e.g. the process of "Mapping of the idea" described in Ottersten and Berndtsson (2002). We went through the material in order to derive a core activity to organize our design around.

Looking for goals and concerns

Several books argues that the users' goals in different activities need to be in focus in the design process (Cooper and Reinman, 2003; Preece, 1994). Identifying the goals, it is argued, is the best way to learn what goals the new system should meet. In our process, we also wanted to get a more detailed analysis of the *concerns* that shape the process towards the goal.

Looking for limitations

After identifying goals and concerns, we therefore continued with thinking through the current system and how that system supported the concerns of the practitioners. In relation to what we had noticed in the field study and concerns in relation to the new system that should support center-to-center coordination, we started to look for limitations in what the users could do or see through the current system.

Formulating requirements

We were inspired by the requirement organization in Löwgren and Stolterman, (1998) and above all the steps described in Ottersten and Berndtsson (2002) in which the authors suggest an organization of the requirements into Effects, Properties and Functions. We chose to make Properties and Functions into one category and we added a category that would help us remember what observation that made us suggest the requirement.

Conceptual sketching

As a first step towards the interface design was the sketching phase (see e.g. Löwgren and Stolterman, 1998; Ottersten and Berndtsson, 2002).

Interface scenarios

In order for us to get an overview of the system we made interface scenarios (Cooper and Reinman, 2003), we went through the process and developed different screens for different situations that (examples from the ethnography) and used arrows to display how the imaginary system would generate the different views (Preece, 1994).

Final implementation

The final implementation produced a small working web-based prototype.

3. Work practice in centers of coordination

> "Centers of coordination are characterizable in terms of participant's ongoing orientation to problems of space and time, involving the deployment of people and equipment across distances, according to a canonical timetable or the emergent requirements of rapid response to a time-critical situation."
> (Suchman 1993a, p. 42)

The term "centers of coordination" was first used by Suchman to describe the characteristic work that is going on in command and control rooms and similar settings. Centers of coordination are settings where collaboration is crucial and updates of the current state of work need to be made in real-time. Many studies have reported on the awareness of 'what is going on in the room' as an important and crucial factor (Heath and Luff, 1991; Norman, 1993; Suchman, 1996). Typical centers of coordination are air traffic control, and train control (Garbis, 2002), but they can also include less safety-critical control work, for example luggage handling at an airport (Suchman and Trigg, 1991) or wastewater treatment plants (Bertelsen and Nielsen, 1999).

Often the subject of control, for example airplanes or trains, is not within reach for the controllers or operators. This means that they are heavily dependent on representations and tools to read and manage the current state of affairs.

> "Centres of coordination are designed to maintain two contradictory states of affairs. On the one hand, to function as centres requires that they occupy a

> stable site to which participants distributed in space can orientate, and which at any given moment they know how to find. At the same time, to coordinate a system of widely distributed activities, personnel within the site must somehow have access to the situation of others distant in space and time. A job of technologies in such settings is to resolve this contradiction through the reconfiguration of relevant spatial and temporal relations." (Suchman 1996)

Work in centers of coordination places heavy demands on the tools and technology used. There must at no time be any ambiguity about the current situation. However, the vast number of sources for the information; screens, printouts, reports, colleagues, etc demand much of the people working in this setting. They must not only know how to read the information they get, they must also know how to combine different sources and know when they have sufficient information for making a decision. The work in centers of coordination thus relies heavily on rules and regulations so that the actors know what to expect. Everyone needs to work in a similar way for the participants to be able to *predict* and *interpret* what others will do and are doing. The work is also characterized by a certain amount of redundancy; checking information and checking again, not only doing the work within the task description but also looking out for what the colleagues do at the moment.

I have done field studies in two typical centers of coordination; in air traffic control and at emergency call centers. Within these two settings there are several studies that illustrate typical work and conditions in a center of coordination. The following section discusses the most influential studies.

Previous studies of air traffic control

The different studies of air traffic control (ATC) have been a resource for understanding collaborative work in complex settings. Especially two workplace studies of Air Traffic Control work have been of great importance to our studies, from the London and Manchester Air Traffic Control Centers by the Lancaster CSCW-group, and Christine Halverson's studies from Denver and Dallas Ft. Worth.

The Lancaster group has studied air traffic control work in control centers in London and Manchester, UK, (Harper et al., 1989; Hughes et al., 1988). In their first major report they thoroughly described the settings in which the controllers work, especially the staff working with en route traffic. The goal of their research was among other things to analyze air traffic control work from a social perspective, examining the team character of air traffic control work, as well as the work practices within these teams. They asked questions such as what characterizes good controlling, and in what way the controllers' trust in the technology they have to rely on affects their work. They also conclude that the controllers' pride and skill is what enables them to keep doing a good job despite the increasing number of aircraft in need of controlling services.

> "Their sense of teamwork, high level of competence at what they do, and, above all, tremendous pride in and sense of responsibility about the service they deliver, enables them to perform their craft despite all the increasing pressures on the service."

(p. 150, Hughes et al., 1988)

In the second of their reports, titled "The Functionality of Flight Strips in ATC Work" (Harper et al., 1989) they concentrate on the use of flight progress strips. They draw many interesting, and at that time, controversial conclusions regarding the role of the flight strip, emphasizing that the physical properties of the strip actually enables the controllers to perform as efficiently as they actually do.

Halverson has done field studies of air traffic control work in Denver Terminal Radar Approach Control (TRACON, corresponding to the work in the Approach control in Copenhagen) and Dallas Ft. Worth Traffic Management Unit (TMU) (Halverson, 1995). In her analysis she used the theory of Distributed Cognition (Hutchins, 1995). Her dissertation is mainly focused on the use of a sequencing and metering system used to control the traffic rates and the metering to keep the aircraft separated, but she also made some interesting observations about the situation for the controllers in air traffic control.

Previous studies of emergency call centers and dispatch

Emergency dispatch centers are also typical centers of coordination. The studies of the domain have taken on rather different perspectives. In Whalen et al. (1988) there is a tragic authentic case analyzed. The miscommunication between the caller and the receiving operator and emergency nurse leads to the death of a woman. Whalen et al. make an ethnomethodological analysis of the conversation, in order to understand how the interaction failed. This is an exceptional case, which made top headlines in the city where it happened. The study points to the important fact that it is the conversation in the emergency phone call that is the foundation for the decisions that the operator makes and thus what resource that is sent out.

The first problem in the case arises in the following section (only conversation included):

D=Department Desk Operator, C=Caller

D: Fire department

C: Yes, I'd like to have an ambulance at forty one thirty nine Haverford please

D: What's the problem sir?

C: I don't know, if I knew I wouldn't be calling you all

This part very well describes the nature of the call. The caller thinks that he is calling to order an ambulance and he gets angry when he has to explain why. The attitude and cursing which occurs later on in the call makes the nurse angry and she does not take him seriously. The conversation finishes when the caller gets tired and does not want to answer questions anymore. When one reads the transcript it turns out that the caller has given information that shows the life threatening situation but presented it in such a way that the nurse does not react upon it. Summing up the important cues the nurse got (I have removed the pauses and the transcript just shows what was said):

Line	Text
11	It is my mother who needs the ambulance
50-51	she is having difficult in breathing
61-62	you can't speak with her. She's seems like she is incoherent

77-78	this is a life threatening situation
89	she could die if you don't hurry
95-96	she is in there and can't breathe
99-100	she is having difficult in breathing, she cannot talk
129	she is incoherent
136-137	she is incoherent, she cannot talk
139	she cannot talk at all
150	she can't talk
151	she can't talk

(For a further description of this case, see Ibid.)

This incident generated a lot of media attention. The question that everyone asked was how could this happen? Whalen et al. use this question as a starting point for their analysis. It seems that the expectations on information to be given are so different that the nurse and the caller cannot understand each other. The nurse does not seem to get a "label" of the accident at the times she asks for them. A label is however provided at other places in the talk, e.g. line 50-51 above. Whalen et al. write:

> "Our investigation revealed that the participants had rather different understandings of what was happening and different expectations of what was supposed to happen in this conversation. Over the course of the interaction the talk of both caller and nurse-dispatcher (and her supervisor) operated to extend and deepen this misalignment. This misalignment contributed in a fundamental way to a dispute that contaminated and transformed the participants' activity: the eliciting and giving of information concerning the condition of the caller's stepmother was displaced with the activity of arguing." (p. 358).

The emergency phone call is not a neutral exchange of facts. The account of the caller is affecting the judgment of the receiver. The emergency phone call made by a layman is perhaps the weak link in the emergency dispatch work. However, the receiving operators must not get "blind" to the facts that are conveyed. It would be interesting to know how much the documentation tools that the nurse used added to the special order she needed things to be in. The case resulted in the nurse being fired because of her failure to receive information in the wrong order.

Whalen and colleagues' research aimed at discussing the incoming emergency call while the next study concerned the receiving and establishing of a case in the control room.

In his Ph.D. thesis, Henrik Artman (1999) focused on cognition in dynamic command and control centers. In understanding the coordination in these centers, Artman draws on the Distributed Cognition perspective where representation, task and activity are analyzed separately. He takes great interest in the parallel and yet group relevant work and decision making that take place. Communicating parallel processes, what each participant does, requires extra focus on informing about all things that are going on. Access to, and presentation of, information is thus crucial for supporting an awareness of other's activities. One point that Artman makes is the importance of the common room, and the possibility to support and provide an awareness of the situation by visual cues.

One of the potential problems with the common room is, according to Artman that too many people tend to get involved when there is a problem "…everyone throws themselves over the nearest problem at hand and try to solve it together. This often results in many people getting involved in a rather simple problem and add more perspectives than is really needed, which makes the problem-solving slower than if one person would have taken care of the problem" (p 118, Ibid.)

Artman also warns about the effects of new technology, although it is needed:

> "New technology is necessary and often brings positive effects /…/. But new technology may have short-term positive effects but in the long run destroy social practices that have been built up by generations of operators."
> (p 119, Ibid.)

Although this is not a surprising opinion, I agree that the social practices have to be considered and to some extent evaluated so that new technology does not hinder informal trajectories of information. People will always use the possibilities and constraints of the situation as resources to accomplish interaction, and they are flexible. However, it is important to understand what these possibilities and constraints of the setting offer and to what extent they are used and relied on.

Artman and Waern (1999) take an interesting focus on the construction of cases at SOS Alarm. They write that "this /data/ shows how the knowledge and interpretation processes are distributed between the operators." In that sense, Artman and Waern see emergency case establishment as a shared task. This means that deciding how to categorize an accident and what resources to send is made through a negotiation amongst the operators, even if it at first sight look like one operator's responsibility. The conclusion suggests that operator work, however individually divided, is largely dependent on others in order for it to run smoothly.

The next study is focused on the dispatch process and the interaction between the dispatcher and the supervisor and the technology. Martin et al. (1997) have done a study of coordination between the dispatcher that is responsible for sending out the ambulances and the supervisors that oversee the work of the dispatchers at an Ambulance Control Center. They were interested in the way the actors organize the distribution of ambulances; the methods that they use in order to achieve interaction in this context. One aim for their study was to compare this site, where computers are a part of work practice, with the control room studies made in London Underground, (Heath and Luff, 1992a), and Air Traffic Control, (Hughes et al., 1988). The results in these previous studies pointed towards the importance of easily manageable non-computerized materials used for coordination.

A difference from my own studies of emergency dispatch is that in the study of Martin et al., there is almost no communication going on between the receiving operators and the dispatchers. Another difference is that there is no role such as the supervisor in the Swedish setting. The article by Martin et al. is not very clear on the general division of labor between these two roles, saying mainly that the supervisor manages the dispatch and keeps an overview of the whole area. Even though one of their conclusions is that the division of labor is an ongoing process (so-called working division of labor), it would have been useful to learn more about their formal task differences.

An interesting part of the paper concerns the contingencies that the dispatchers face when choosing a vehicle. When looking superficially at the work that they do, it seems that selecting the nearest available ambulance would be a suitable practice. However, there are a number of things to consider: work hours, meal breaks, vehicle equipment, maintaining an even distribution of vehicles ready to go in the areas, etc, etc. Martin et al. make the point that since these contingencies may be significant, there is a greater need of information than just knowing *where* the ambulance is geographically located. With support from their study, Martin et al. make the conclusion that a GPS map, following the geographical locations of the cars is time consuming and not very useful for selecting which unit to dispatch. This is because it is only possible to extract part of the information that is needed when deciding which vehicle to dispatch and the map itself does not give the piece of information fast. The operators have to search for it e.g. "where do I have car x…oh there it is…and how far is that to Z road…perhaps car Y is closer". Thus their point is that it takes time to look the information up on the map and it does not include all contingencies that will be used for the final decision on which vehicle to choose. Contingencies are for example if the unit is due for a break soon.

In the end of the paper, Martin et al. (1997) give the outlines for a further development of their study in making a prototype of a new system. The work is guided by four conclusions:

- Contingencies are interactionally managed (negotiation of choices). This is a similar conclusion to the one made by Artman and Wærn; interaction, rather than individual work accomplishes the choices and categorization work.
- Division of labor is continuously worked on.
- Representations are work-oriented. (It is not always the most advanced graphical representations that are useful. In time critical settings, simplicity and the possibility to perform a task fast are the two main foundations for a good tool.)
- HCI is a public phenomenon (design for third parties). When the dispatcher is carrying out a task, the supervisor can understand his/her turning the head towards the information that needs attention. By seeing what the operator is attending to, the supervisor can help without the operator asking for it. A question that Martin et al. raise is thus how well a tool helps others than the immediate user to understand what is going on.

Coordination and technology – concepts

There are a number of workplace studies that have described different kinds of social practice. The section below goes through the ones that have guided the analysis and understanding in my studies.

Tool-mediation and double level language

Most activities that we do involve different tools that we are dependent on. It is therefore no surprise that coordination is often helped by and dependent on tools. The word "tool", as used here, has a wide range of meanings. Any object, artifact can be used as means for coordination. A basic assumption is that manipulation of tools is explicitly or implicitly used for coordination. Pål Sørgaard (1988) gives an example on how an object mediates coordination:

> "A simple example is the way two people carry a table. A part of the coordination may take place as explicit communication, for example in a discussion of how to get a table through a door. When the table is carried, however, the two people can follow each other's actions because the actions get mediated through the shared material. This coordination is not necessarily explicit."

Typical tools that we use for explicit coordination are those in which we can imprint a message; write or record them. There are a vast number of tools that surround us, which communicate written messages, for example the sign on a door saying "Occupied". An implicit coordination tool can be any object that through its placement, alignment or modifications conveys a message. These two kinds of coordination (explicit and implicit) constitute what Sørgaard means by "double level language" and the messages are strongly connected to the context. A simple example: to keep our seats in a train we might put our jacket in the seat when going to buy coffee in order for others to see that this seat is taken. We understand this cue not because it is a part of a universal language for keeping our seats, but because we are familiar with the activity of going by trains. If someone would remove our jacket and take our seat, we are somewhat rightfully in the position of being allowed to ask that person to move.

Since the implicit cues that we use for coordinating with people around us are so dependent on the context, it can be assumed that every professional context has its special cues that others, laypersons, would not at first sight understand. When planning a redesigned system for work, I believe it to be important to know what kind of cues that the professionals depend on. Zuboff (1988) gave an example where office workers made little holes in the cubicle walls in order to have some awareness of each other's activities. The walls were blocking the informal contact that they felt was important. Robinson (1993) writes:

> "Implicit communication can only happen when the participating actors are able to *maintain* an evolving set of rules, understandings, and expectations about the meanings of actions, signs, and changes of the common artifact/…/."
> (p. 195)

In order for one to use, say the jacket of your colleague on a chair, as anindication that s/he is at work, it has to be a recurring phenomenon. The familiarity with an object and its usual placement (or the missing of it) that is used for a cue is necessary for implicit communication to happen. Again, the inside perspective of a competent member becomes the possibility to interpret information.

Coordination mechanisms and articulation work

The quote above could very well be a starting point for the research done on Coordination Mechanisms. Kjeld Schmidt is the researcher that most often is connected with these theories. He and his colleagues have worked on a conceptual framework for coordination mechanisms (Schmidt and Simone, 1996). They use the concept of CM not in the everyday sense but have an intricate description of the phenomena that surround artifact use for coordinative purposes. Schmidt and Simone make 26 propositions based on knowledge from a set of field studies on the use of artifacts for coordination. The question is how to reduce the complexity in cooperative activities. In the framework, several analytical distinctions and concepts are defined, many of them related to *articulation work*.

Proposition 1 makes a distinction between cooperative work and articulation work:

> "*Cooperative work* is constituted by interdependence of multiple actors who interact through changing the state of a common field of work, whereas *articulation work* is constituted by the need to restrain the distributed nature of complexly interdependent activities." (p. 158 ibid.)

Articulation work occurs when the *field of work* is *complex*, and there is a need to communicate activities to reduce the complexity. The field of work is the alterable material (concrete or virtual) that people at a work place are working on. That could e.g. be a database for bookings that several persons work on. Complex work situations are those where the current state of the field of work is (or may be) ambiguous and the field of work is dynamic and unpredictable. Schmidt and Simone (1996) write:

> "To deal with this source of confusion and disorder, individual and yet interdependent activities must be coordinated, scheduled, meshed, integrated, etc. – in short: articulated (the word 'articulated' is used in the sense of 'to put together by joints'). That is, the orderly accomplishment of cooperative work requires what has been termed *articulation work*." (p. 158)

In Proposition 2 Schmidt and Simone point out that articulation of work and cooperative work are recursive, in that the way of articulating work may be in need of cooperative negotiation, and that the result of it may be in need of articulation. Take for example a classroom with traditional settings for learning, teacher in front and several pupils facing her. In order to make sense of what is taught in the group, there is a need for attention. Hence, the rule of raising one's hand before speaking. The cooperative work consists of various contributions to the topic of discussion, whereas the articulation work is the lifting of the hand for reducing the complexity of several people in a room that are speaking jointly. A recursion of cooperation and articulation work would in this case be initiated by a suggestion that there should be a change of the articulation of wanting to say something, i.e. raising ones hand. One pupil suggests that the teacher's role of appointing the current speaker should be removed and there should be a stick to exchange between the talkers and move the word around with. In discussing this, the class makes a cooperative effort, which later may result in a change in the articulation of wanting to speak.

Proposition 3 deals with the role of the artifact in cooperative work (ibid.):

> "In cooperative work settings characterized by complex task interdependencies, the articulation of the distributed activities requires specialized artifacts which, in the context of a set of conventions and procedures, are instrumental in *reducing the complexity of articulation work* and in alleviating the need for *ad hoc* deliberation and negotiation." (p. 162)

The coordinative functions of artifacts are reportedly a very important aspect in complex work settings. To be able to see and communicate what others are doing and what the states of different tools are, is crucial for the coordination of work (Berndtsson and Normark, 1999; Harper and Hughes, 1993; Heath and Luff, 1992a; Suchman, 1993b, among many others). The important issue here is dealing with the complexity of work. As reported in the studies mentioned, numerous ways to reduce complexity have been developed. In the case of air traffic control, we have studied how a simple surveillance camera system is used for coordination of the important flight strips in the rack, see Berndtsson and Normark (1999). By using the cameras and monitors, the distribution of information is reduced and the controllers have the information at their own work suite. The amount of relevant information that has to be coordinated through – what is experienced as - obtrusive phone calls is reduced.

In proposition 4, Schmidt and Simone suggest that an *artifact* with *a coordinative protocol* is a coordination mechanism. They emphasize that the coordinative functions of the artifact should in some way include a protocol, i.e. a plan. They illustrate a coordination mechanism by the bug report forms used in a software development project:

> "On the one hand, we have a *coordinative protocol* in the form of a set of agreed-to procedures and conventions which, to competent members of the ensemble, stipulates the responsibilities of the different roles, the possible classifications of bugs, the intricate flow of forms, acknowledgments, reports of bugs corrected, etc. On the other hand we have the bug report form as *an artifact*, i.e., as a distinct and persistent symbolic construct, in which the protocol is imprinted and objectified." (p. 165)

Awareness

Awareness means to sense others activities, either through hearing or seeing (or possibly using other senses); draw a conclusion, and make use of that conclusion in one's own activities. This could either be directly, for example when you see colleagues passing in the corridor, or it could be indirectly through for example seeing that someone is uploading a file on a shared computer system. Awareness of each other's activities is essential for coordination of work, so it is interesting to see how tools are used for improving awareness of the general state of affairs. Consider the example that Zuboff gave about making a hole in the cubicle wall; the office workers were not able to see details of what their colleagues were doing, like seeing what they read, but they got a general idea of what was happening, possibly from the posture of the person they looked at and their knowledge of how the cubicles were equipped (Zuboff, 1988).

When working in the same office, for example, we can achieve awareness of each other's activities from the shared physical environment; steps in the corridor, talk heard through walls, printers printing, etc. The real challenge is to support awareness in distributed work. Hollan and Stornetta (1992) state that "there is a predictable fall-off in likelihood of collaboration between two researchers" in distributed settings, even if they have the same interests and are at the same organizational level. A likely reason for this is said to be the lack of informal interaction and awareness of what is going on that creates the common ground for the maintenance of a relationship. A basic presupposition is that it seems to be more difficult to get an informal relation in a distributed setting compared to a co-located setting. How can we record the steps in the corridor, the schedule outside the meeting rooms, the informal encounters in the hallway, etc so that we can get a similar kind of awareness at a distance? Schmidt (1998) writes:

> "From a CSCW perspective, the crucial point about the concept of mutual awareness is to understand how mutual awareness is produced, i.e. (1) how information pertinent to mutual awareness is provided and acquired by members of the cooperative ensemble, and (2) how the characteristics of the work setting constrain and afford the provision and acquisition of information pertaining to mutual awareness."

As Schmidt and Simone (1996) point out, one aspect of coordination work is that, as a competent member, you actively provide the cues that you know your colleagues need for their work. It is part of being a competent member to be able to predict what others will be interested to know. A quite common example at least in the academic world is keeping your office door open or closed. It is often a sign of the level of privacy that is requested by the person in the room.

Juxtaposition of sources

A professional knows how to combine information in order to interpret the current situation.

> "The mutually constitutive relation of actions and their environments includes the fact that accounts of activity are themselves crafted from the juxtaposition of observable features of embodied actions with phenomena selected from the scene in progress /.../." (Suchman, 2000)

This concept is especially useful for control room work, where the professionals have to make fast decisions based upon different pieces of information. How are the pieces combined? How do they make sense of the information? Suchman reports from a study of luggage handling at an airport:

> "A central finding of our analyses concerns the extent to which the work of Operations involves the assembly of knowledge about past, present, and future events through the juxtaposition and relationship of a diverse range of technologies and artifacts. Access to information and its timely communication to relevant others involves interaction not with a single technology but rather with multiple technologies (e.g. forms, computer screens, video monitors) held in relation to each other and read off in ways specifically structured by the task at hand." (Suchman, 1993a)

From what is known about control room work, the time constraint largely effects that the work is organized . The possibility to get information, at the right time and at the right place and to be able to integrate it with other sources is essential.

Boundary Objects

What do the boundaries of an object represent? In order for an object, or anything at all, to get a specified boundary, there needs to be some kind of categorization. Take a chair for example. In some contexts it is an item for sitting. If the same object would be used for children's building of an indoor tent, it would be a tent pole. Depending on the context, the boundaries for what it is and does change.

> "…we define boundary objects as those objects that both inhabit several communities of practice *and* satisfy the informational requirements of each of them. In working practice, they are objects that are able both to travel across borders and maintain some sort of constant identity. They can be tailored to meet the needs of any one community /…/. At the same time, they have common identities across settings. This is achieved by allowing the objects to be weakly structured in common use, imposing stronger structures in the individual-site tailored use. They are thus both ambiguous and constant; they may be abstract and concrete." (Bowker and Star, 2000)

The boundary object and the discovery of boundary objects at a workplace have serious consequences for the understanding of work and design of new artifacts. If an object (the same object) is considered a chair by one part and a tent pole by another, many confusions may arrive when redesigning the object.

> "Such objects have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities." (Ibid. p. 297)

Of course, maintaining an object within an organization that is categorized differently by different members requires a lot of effort. Values, names, use, meanings and priority are all things that come with an object getting classified. Managing these different views creates a further complexity between colleagues, groups, departments or organizations.

4. Field study results, ATC

ATC work

This chapter describes air traffic control work based on the two studies at Copenhagen Airport and Shannon Airport. It mainly discusses the Copenhagen setting because that was the large study while the study of Shannon was a short follow up study. The work has many similarities. One of the main differences that was noted is discussed in paper B.

Air traffic control work is about maintaining safe and cost-effective air traffic. This is done through keeping the aircraft separated from each other by talking to and giving instructions regarding height, speed and route to the pilots, as well as giving them information about weather conditions etc. Or as one of the controllers described his work:

> "I make sure that the aircraft that are going to take off and land get the most appropriate route, height, most cost effective, fastest, provided the safety is uncompromised."
>
> (Controller in Copenhagen ACC)

Although it may be self-evident, it is important to point out that the safety is the first and foremost concern of the controllers. However, route and flight level changes are not only made for safety reasons, they are often being done as *a service* to the airlines, allowing the pilot to get a faster or more economic route, e.g. to go directly to certain waypoints, or to get a more favorable altitude.

Safety in air traffic control to a large extent means keeping the aircraft separated. This can be done by differences in altitude, i.e. flight level separation (minimum 1000 feet apart), through separation in distance, longitudinal separation (queuing with three or five miles apart depending on the current location of the aircraft), or through providing the aircraft with different routes. Keeping aircraft separated might seem as an easy task, but given the amount of traffic traveling through Danish airspace every day the work is complex, and it is controllable only through the skills of the controllers and an extensive use of conventions, procedures and tools. Without these a lot of negotiation and information coordination would have to be done.

By dividing the air space into sectors, geographical areas, the work is organized in manageable pieces. The Danish airspace consists of nine en route sectors, divided into four upper and five lower sectors. Each sector is manned with one or two controllers, one radar controller who watches the radar and talks to the aircraft through the radio, and one planner controller who manages the strips and talks to adjacent sectors (as well as handling other phone calls), and a sector assistant. If there is only one controller, s/he is both controlling the radar and managing the strips.

Air traffic control work could be described as surveying and managing the sky (Harper et al., 1994). However, in pursuing the tasks included in this activity the controllers also need to coordinate their work with others. Since most aircraft pass through more than one sector, and all of them need to take off and land at some point, the aircraft is shifting not only between geographical sectors but also between controllers. This also means that the work done in adjacent sectors can be of interest, and thus to some degree has to be visible to the other controllers, enabling them to both plan their own work ahead, and see how they best should hand over the traffic to the following sector controller.

The en route airspace is divided into geographical areas, or rather volumes of air, called sectors, in order to distribute the work among the different controllers. The Danish airspace, Copenhagen FIR (Flight Information Region), is divided into nine sectors, four upper and five lower. But there is also another division that has shaped the way that the work of controlling is arranged. The traffic controlling of the Danish Airspace from the Copenhagen Control Center can be divided into four different controlling units:

1. The ground around the runways, e.g. the taxiway, the parking space, etc. is handled by the Apron Tower.
2. The airspace immediately around the tower, and also the runways, are handled by the Tower control. The area is used for controlling take off and landing of aircraft.
3. The Terminal Maneuver Area (TMA, or 'the approach area' which is the term used at Copenhagen Airport). This area is used for approaches to, and departures from, the airport (this responsibility area approximately covers Shetland, the island where Copenhagen airport is located), and is managed by the Approach Control. The area is divided in two, one W/N (West/North) and E/S (East South) area.
4. The Danish en route airspace is handled by the Area Control Center (ACC). It is divided into nine sectors, four upper, and five lower.

It is likely that an aircraft crossing Danish airspace will pass several of these sectors and therefore be controlled by several different controllers on the way.

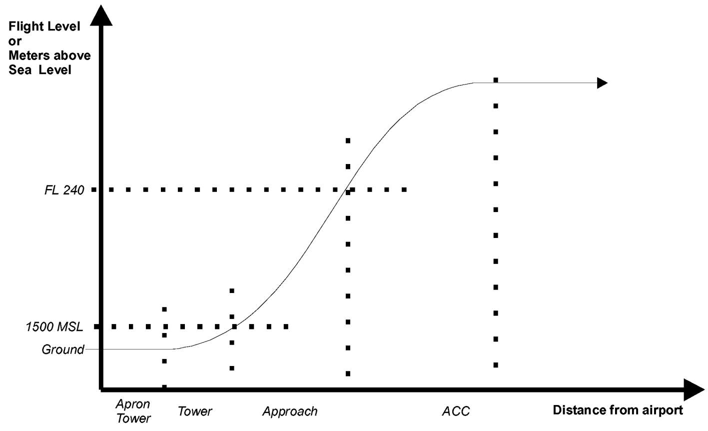

Figure 1: A departure from Copenhagen Airport showing the hand over moments between the four controlling units: the apron tower, the tower, the approach control, and the ACC (en route) control.

All these different departments are located in different places. The Apron Tower is a separate building (a tower), located close to the gates to enable the staff to see some of the gates through the windows. The tower is also in a separate building (a tower), overlooking the runways. The Approach control and the ACC actually share a large room but they are sitting in different parts of this room (see Figure 2).

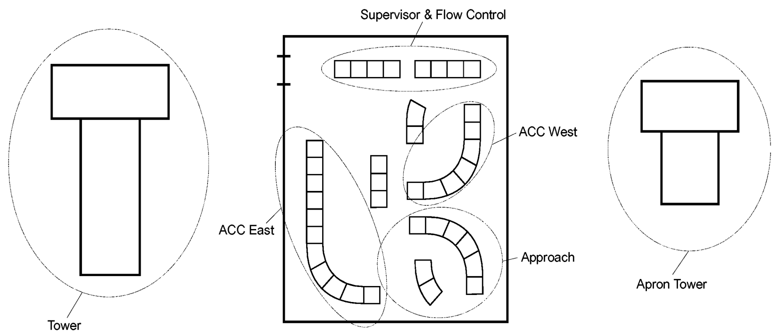

Figure 2: Sketch showing the buildings from where the controlling is being done, including an overall layout of the Copenhagen Air Traffic Control Center.

ATC skills

During a departure the responsibility for the aircraft is handed between different controllers several times (in Figure 1 this is represented by the vertical dotted lines). A hand over is regularly performed through the controller currently responsible telling the pilot to switch frequency on his radio and contact a controller in the next sector or airspace, e.g. 'Scandinavian niner eight seven, contact approach on one one niner decimal one'.

The Approach sector

The Approach control is handling an area of the size of, from about 1500 meters above sea level up to flight level 240 (24.000 Foot, approximately 7.800 meters). When it comes to arriving traffic the function of the Approach sector could be seen as that of a funnel, where the ACC are pouring arriving traffic into the funnel from above. Within the funnel the controllers order the traffic into one steady stream. This ordered stream of traffic is then delivered to the Tower controllers.

The airspace in the approach sector is divided into two parts, one W/N (West/North) and one E/S (East/South), and there is also a small area called Final.

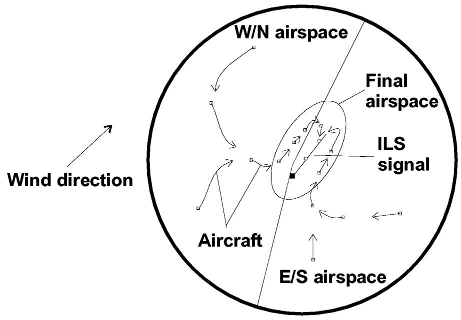

Figure 3: The division of airspace in the Approach sector (W/N, E/S, and Final airspace) as viewed from a radar screen. The W/N and E/S controllers receive aircraft at their respective inbound waypoints, line them up in two queues, and hand them over to the Final controller, who merges the two lines into one, and then hands them to the Tower controllers.

There are standardized landing procedures to land at Copenhagen Airport (STARs, Standard Arrival Routes), which every approaching aircraft has to follow. In these STARs, certain navigational waypoints, so called inbound waypoints, have been specified as entry points into Copenhagen Approach. The controllers working in the APP W/N sector handle aircraft coming in over the inbound waypoints SVDA, TRANO and KORSA, and the controller in the APP E/S sector handles arrivals from CORSA and ALMA. Their job is then to line these aircraft up in one downwind[3] stream from W/N and one from E/S, and hand them over to the final controller. This hand over is performed by the W/N or E/S sector controller asking the pilot of the aircraft to "contact final" at a specific

[3] Aircraft have to land against the wind. Downwind means *with* the wind, and lining them up in this seemingly wrong direction gives the Final controller the time to arrange the two streams of aircraft by turning the aircraft towards each other, merging the two lines into one.

frequency, and gives the flight strip to the final controller who, as shown in the figure, sits between the controllers who handle the two approach sectors. The Final controller therefore handles aircraft from both sectors and leads them up in their two respective queues to a point where they can turn (i.e. he orders them to turn), be merged into one queue - not unlike the way a zipper works. Or, as expressed by one of the controllers:

> "You make sure they get in, they are… who is number one, two, three, four, five etc. etc. They are interplaited, and finally thread like pearls on a string, ready to land on for example runway 22 left."
> (Tower/Approach controller in Copenhagen)

Once lined up heading straight for the runway, the pilots can find the ILS (Instrument Landing System) signal and use it to land. When the aircraft is established on the ILS the Final controller orders the pilot to contact the tower controller and the aircraft is thereby handed to the tower.

Most of the time only one controller handles the work in APP W/N respectively in the APP E/S. But, when the workload is heavy, the work with W/N and E/S respectively will be split up into two different roles, one handling departing aircraft and one handling arrivals. The basic positions, the ones that are used if only one controller is working the sector, are the ones closest to the left and right of the Final position. They are also the ones from where arriving aircraft are always controlled.

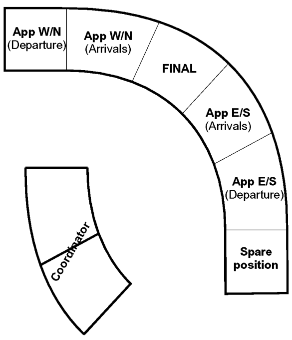

Figure 4: The work arrangements in Copenhagen Approach. The Final controller is sitting between the controllers handling arriving traffic, a position that enables verbal as well as non-verbal communication.

Figure 5: The approach control. Photo taken from the left in the sketch in Figure 4.

This arrangement has lots of benefits since the workplace is designed to have the controllers who need to coordinate their work close to each other. E.g. as mentioned, the Final controller always has the controllers handing him aircraft next to her or him, facilitating the possibilities for both verbal and non verbal communication. And since the Final controller has nothing to do with departing aircraft, expanding the positions with departure controllers placed away from the Final controller, but close to the controllers handling arriving aircraft in the same sector, works fine, since it enables the same kind of elbow communication between the arrival and the departure controllers.

The controllers in the W/N and E/S positions are also handling the departing aircraft, which later on will be handed to the en route sectors in Denmark and Sweden. Similarly to the approaching aircraft STARs, the departures are predefined through SIDs (Standard Instrument Departures), precisely defining the route which each departure will take.

There is also a third role involved in the work with approaching and departing aircraft, the Coordinator. The coordinator's main task is to support arrival and departure and give airway clearances (basically formal allowance to the pilot for the flight) to the two minor airports in the area, Roskilde and Værløse. S/he is also taking phone calls regarding some of the changes in altitudes and routes for approaching aircraft. These messages are then passed on through either talking out loud to the concerned controller, or by going over to the controller and make changes to the controller’s strips while briefly informing her or him about the new situation.

Tools and Procedures

To deal with the complex and time-critical work of controlling, the controllers have to rely on an extensive amount of procedures and tools. Well-applied procedures reduce the amount of time that would otherwise be spent negotiating with adjacent sectors, pilots and other people.

The division of airspace into sectors as a way of enabling a structured way of handing over aircraft between sectors, but there are many others, such as the agreements regarding standard flight levels at hand over between sectors, and the standard entry points for approaches, etc. Also, the three years that the air traffic control students spend in school, a lot of the time is devoted to learning rules, and practicing the application of them on simulated air traffic. In fact, there are standard procedures for almost everything, and in the way they are used within air traffic control work they can in many cases be seen as silent coordination between controllers – they know what to expect, where to expect it, and how to handle it, thanks to procedures.

However, procedures do not solve everything. To cope with the demanding situation, air traffic control work involves many different artifacts supporting the controllers in a wide variety of ways.

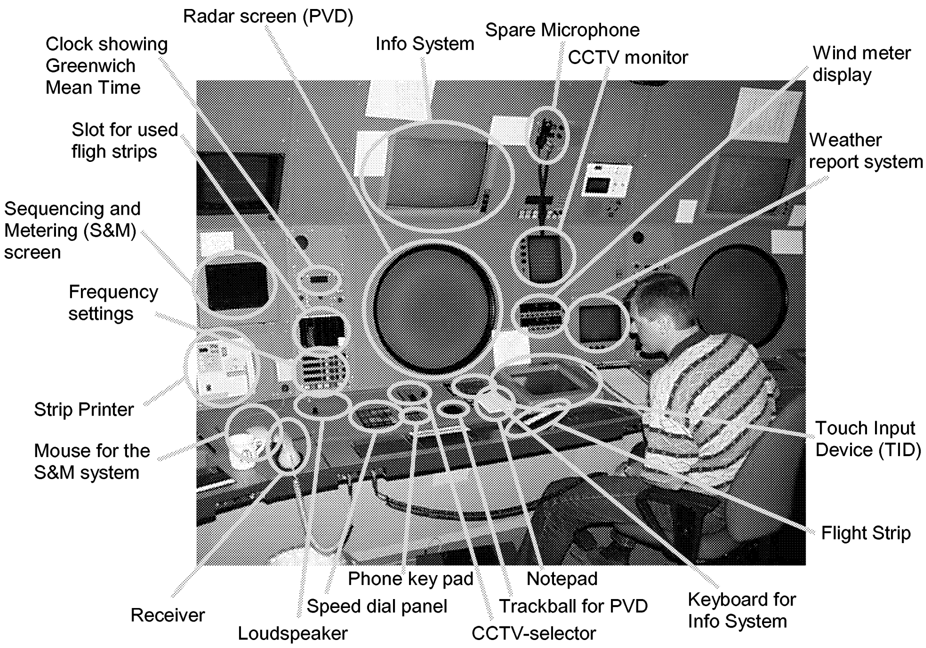

Figure 6: There are many different tools available to the controllers. In the figure, showing the approach E/S position, the most prominent tools are pointed out.

Some of the artifacts pointed out in the Figure 6 are aimed at enabling the controllers to be aware of the current situation in the sky, such as the radar. Others are designed to reduce the time it takes to perform recurrent tasks, such as the speed dial panel for the telephone on the controller's positions. However to cope with the distributed settings described above there are also artifacts specifically designed to facilitate coordination of the controllers' activities in the different control rooms, and these are the ones we have chosen to focus on in our work. It is, however, also important to notice that procedures and conventions, e.g. regarding the signs written on the flight progress strips, support the use of these tools.

Another important point when it comes to these tools are the way in which they are interconnected with each other. The flight plan database and the radar system provide the controllers with much of the information they need in their work, regardless of whether it is accessed through the radar screen, the flight strips, or the sequencing and metering system.

Even though the tools and procedures are presented here as single entities many of them are thus interconnected, and the effect of their combined use is what really makes this system work. Therefore the following descriptions of the tools used by the controllers are somewhat interweaved.

The flight plan database (with flight strip printouts) and the CCTV-system

As described earlier an airline has to submit a flight plan to Eurocontrol before commencing a flight. Eventually, this flight plan ends up in the Copenhagen flight plan database. Some of this information, together with calculated values for e.g. estimated time of arrival etc., is then printed on paper as flight strips in the sectors concerned.

A flight strip (also referred to as the 'flight progress strip', or 'strip' throughout this report), is a rectangular strip of paper containing printed, and eventually hand-written, information about a flight. The main function of the strip is to provide the controllers with representations for each flight, enabling them to plan their work a few minutes before the aircraft has reached the point in question.

Each sector position has its own strip printer, which is either handled by an assistant or a controller, where strips are being printed for every aircraft that is passing through the sector. Thirty minutes before an aircraft enters a specific sector a first flight strip, a so-called warning strip, which is based on the data in the flight plan database, is printed in the sector. Subsequent strips for the same flight are then printed twelve minutes before the aircraft is going to enter the sector, and also each time the flight plan in the local database is changed. When printed, each strip is mounted in black plastic holders and placed in columns on a flight progress strip board. When updated strips are printed these are placed on top of the old ones in the same plastic holder. When this happens the system marks the change by inverting the text that has been changed, e.g. a change in the estimated time of arrival for SAS123 (ETA 09:34) will be written 09:38 (white text on black background).

There are also some sectors in which there are several strips for the same flight, but where the strips are not replacing each other since the data on them refer to different significant waypoints. The sector N can for example have up to three strips for each flight.

Each strip contains a large amount of information, such as e.g. estimated time of arrival to the next waypoint, flight level, call sign, speed, squawk code (transponder code) etc.[4] This information is also arranged in a specific manner, enabling the controllers to know where to look for which information (see

Figure 7). Since the apron tower, the tower, the approach, and the en route control all use different layouts for their strips there are however differences depending on where the strip is being used.

Time	Waypoint	Flight Level	Identification	Miscellaneous	Notes

Figure 7: The basic structure of an ACC (En Route) flight strip in Copenhagen (there are several kinds of strips, structured in different ways).

This specific way of arranging the information is very important since it is actually the location of the numbers on the strip that tells the controller if the numbers refer to an altitude or a heading – information that must not be mistaken. There are also rules and strong conventions regarding what to write within each field, and how to write it. The only 'free' space is the field for notes.

Figure 8: En route strips from sector B. A view of the whole strip rack is available in Figure 9, page 40.

As shown in Figure 8 the estimated time of arrival (ETA) is the leftmost data on the en route strip. In the next field the waypoint that the aircraft is heading towards is specified (here, CDA, or "Codan"), and in connection to this there is an arrow pointing out the general heading of the aircraft.

Based on set agreements between the different sectors the aircraft is expected to be handed to the sector controller at a prescribed flight level that is printed in the third column of the strip (an arrow is here used to mark descending or ascending aircraft). This agreement can be changed for a number of reasons during the execution of the flight, and if so, the controller will handwrite the new altitude in the same area of the strip. The controller also makes other kinds of marks, e.g. underlining an altitude if the aircraft is 'maintaining' the specified

4 The exact number of possible pieces of information is 56 (see Appendix I for more details).

altitude.

The call sign, written to the right of the flight level field, is the identification of the aircraft. It is based on the name of the Airway Company. Scheduled flights have the same call sign each time the flight is made. For example, SAS has a daily flight to Munich with the call sign SAS1661. In this field the aircraft type and weight class are also specified.

Another important identification number is the transponder code. This is the code that is entered in the aircraft transponder in order to make it possible for the radar to distinguish and identify the aircraft. The transponder code is located in the next rightmost field together with e.g. start and destination airport, hand over flight level (to the next sector) etc. The rightmost field is reserved for special messages, such as late changes, and notes about the flight that does not fit in any of the other field categories.

As mentioned above, the strips are organized on flight strip boards. In Copenhagen this organization is based on navigation beacons and estimated time of arrival.

Figure 9: A strip rack with en route strips from ACC-East, sector B.

The columns of the strip board are used to represent geographical separation within the sector. Generally, strips to the right are flights over the eastern part of the sector, and strips to the left over the western part. The darker (red or green) strips, visible in Figure 9, are so called designators. These 'designator strips' contain information about the navigation beacons, as well as holding patterns for aircraft approaching Copenhagen airport. The strips representing the aircraft closest to the specific beacon are placed in the bottom of the bay, and thereby also closest to the controller. In the figure you can see three designators in use (the rightmost bay is currently not in use), one in the left column, and two in the middle. The right column contains unused designator strips. The bottom designator in the middle column, CDA, is an inbound designator (as all green strips are) that represents 'Codan', one of the five inbound designators used for aircraft approaching Copenhagen airport. In this case KLM1174 is closest to the inbound designator CDA, and DLH3092 is closest to the designator GES/CDA. In Copenhagen the strips in each column are therefore sorted according to the sequence of arrival, although other configurations, based on e.g. flight levels, especially used when controlling aircraft in holding patterns, have been reported by other researchers (Harper et al., 1989; Hopkin, 1995).

Another reason for this way of organizing the strips is that there are sometimes several strips for each flight within the same sector. If the aircraft crosses more than one significant waypoint, there will be one strip for each of them. This is the case with the flight OYBIL in Figure 9 (the third strip from the bottom of the left, and the fourth from the bottom of the middle column). Also, in the left column in Figure 9, one strip is placed above the designator. This is one way of handling flights that require specific attention, flights that might behave differently from the flights otherwise navigating the area. In this case the strip is pink, which means that it is a flight strip for a military aircraft.

Another way that the controller can point out traffic that needs attention is to mark the strips in certain ways, to slide the strip out of its normal place in the holder, or to tilt the strip and the plastic holder so the strip 'disturbs' the normal pattern. This way of pointing out e.g. potential conflicts by 'cocking' flight strips has been pointed out by Harper et al. (1989) and can in Copenhagen be done in a number of different ways.

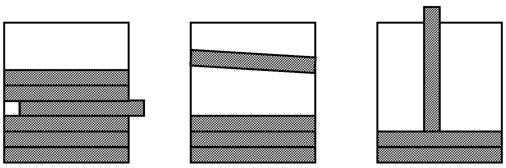

Figure 10: Examples of different ways to 'cock' out flight strips at the Copenhagen Air Traffic Control center.

The leftmost cock out method has been noted in most of the sectors. This is the most common way to indicate that there is something special with a flight. The method in the middle is mostly noted in the Tower, and is used to indicate that the flight represented by this strip is delayed, but normally should be on its way and thus also located further down the strip rack. The third method is noted in ACC and seems to be done mostly in situations where there is little room on either side of the column holding the strip that needs to be cocked. These different ways to cock out strips are not formalized or conventionalized to have a specific meaning regarding what kind of attention that is needed. Upon asking the controllers why they sometimes do one or the other they referred to each controller having his own way of doing it.

Changes concerning the on-going flights are made visible in two ways. One way is to alter the flight plan database, which will generate a printing of a new flight strip in all the following sectors as described earlier. However, since there usually is no time for the quite complicated procedure of altering old or entering new data in the database, changes are often, as we earlier mentioned, handwritten directly on the strip. The old data is simply struck out on the strip, and complemented with the new. Typical changes involve changes in flight level since changes in altitude is the most common way to separate aircraft while they are en route. These changes are being made both to aid the controllers' own memory, and to facilitate for other controllers that are interested in the traffic in the current sector, such as e.g. controllers in adjacent sectors and the change over relief controller.

The functionality of the flight strips are also extended through the use of a closed-circuit television system enabling the controllers to see the strips from different control positions, and thereby also to get quick, and through the hand-writings updated, information about what to expect in the near future. This is described in the following section.

The closed-circuit television system in Copenhagen

The closed-circuit television system was introduced to reduce time consuming and obtrusive phone calls between the controllers managing traffic in the Danish airspace. Technically the closed-circuit television-system consists of cameras linked to monitors via a switchboard. The purpose of this system is to distribute the view of the flight strip rack between adjacent sectors, especially those that keep the responsibility of the aircraft for a short time, as the Approach or Tower control.

Figure 11: En route controller handling both the radar and the planner positions in sector B, ACC East. The cameras are aimed at flight strips for aircraft approaching Copenhagen Airport from the south, the CDA inbound designator.

The cameras together with two spotlights are placed right above the flight strip rack, were the current flight strips are placed. The rack is placed to the right of the controller's shoulders. The reason for having two sets of cameras and spotlights here is that on this position, sector B, several aircraft are entering the approach area from the CDA entry point, and therefore many strips in the rack. One camera is therefore aimed at the bottom of the rack, and the other at the top. This control position also has a closed-circuit television monitor where the controller can see strip racks from any other position. The default setting, however, is to watch the strips from the tower, to see what departing traffic to expect in the near future. The monochrome monitor is placed above the left radar to the right. The picture quality of the monitor is very good, so good that even the smallest text is readable quite effortlessly. There is also a control panel (consisting of a number of buttons) beside the screen, with which the controller can choose from which sector/control room s/he would like to see the strips. These buttons are also used to choose between cameras for sectors where the number of strips that are of interest to other controllers exceeds eight, which is the limit for one camera

The field of the camera used in this closed-circuit television system is very focussed – it only shows the flight strips. The only time a movement is visible on the monitor is therefore when a controller makes notes on a strip (see Figure 12), or moves it in the strip rack.

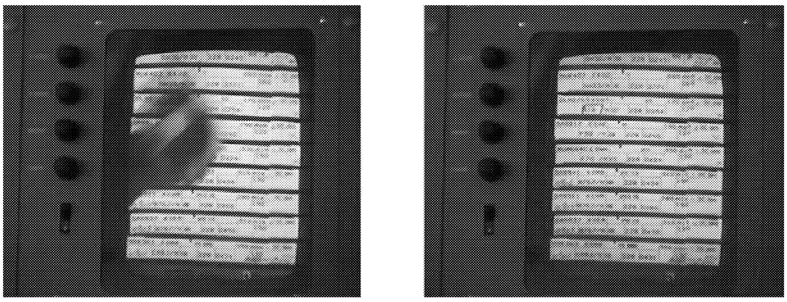

Figure 12: The closed-circuit television monitor from the approach, showing strips from the tower. Both photographs show the same monitor a few seconds apart. The sequence shows a tower controller highlighting (by drawing a box around) the aircraft type of a shortly departing aircraft.

The movement of the controller's hand on the screen alerts the 'watching' controller through her or his peripheral vision that something is happening, allowing him to check the monitor when changes are likely to have taken place.

As a technological system the closed-circuit television system is quite simple:. standard video cameras and monitors that are connected through a video network. However, when looking beyond the pure technology, the system, and the use of it, prove to be quite complex. Its video cameras and monitors practically interconnect all 'departments' working with, or in the immediate proximity of, Copenhagen Approach.

Copenhagen can see Malmö ACC in Sweden, since one of the waypoints for

Copenhagen is placed on the Swedish side of the border. Both Malmö ACC in Sweden and Copenhagen ACC provides the Approach in Copenhagen with information on the traffic around four of the five the inbound designators[5]. The Approach provides the Tower, the Apron Tower, and miscellaneous services, such as e.g. the Scandinavian Airlines (SAS) service center and Aero Cleaning, with pictures from the Final position, showing aircraft from approximately ten minutes before landing. The Tower then provides the Approach and the Danish ACC sectors with pictures showing the departures from Copenhagen. The Tower is also connected to the Apron Tower in that the Apron Tower provides a picture of which aircraft are about to roll out to the runways. Through distributing the 'at a glance' view of the flight strips to the concerned actors the closed-circuit television system makes it possible for the controllers to coordinate e.g. flight levels and the order of the incoming aircraft without time consuming and obtrusive phone calls.

Overhearing at Shannon

Because of the lesser amount of traffic at Shannon airport, the controllers are able to use the radio system to listen in on the adjacent sector's radio traffic to get an understanding of what is going on. They are listening to both their own, and the next sector's, radio traffic.

Figure 13: The approach sector with the loudspeaker that the controller uses to listen in to another sector.

[5] The reason for only covering four of the five inbound designators is that the system was built during the cold war while the amount of traffic back and forth to eastern Europe was still very low. However, with the fall of the Berlin wall the traffic over ALMA, which is the name of the designator, has increased considerably. There have been discussions about installing a fifth camera, but so far no decision has been made.

As can be seen in Figure 13, the controller in the approach sector is using a headset. The radio traffic from the other sector is heard from the loudspeaker. When asked if it was possible to hear something from the outside using the headset, the controllers explained that the headset is supposed to direct the sound on their own radio frequency, but still take in the ambient sound from 'the outside world'. They would not want radio traffic from two frequencies in the headset. One controller explained that after a while, it is possible to listen even if you are talking on the radio at the same time.

The sound heard from the loudspeaker is both a signal that something is happening in the other sector, and more explicitly an indication of what is happening. In the tower sector, the controller is listening in to the approach radio frequency. S/he is listening for the order in which the aircraft are coming in, in order to be prepared for what might occur. It is good to know if for example a heavy aircraft is coming in, since they take more time on the runway. The taxiway from the runway at Shannon is in the middle of the runway and heavy aircraft cannot stop in time for the taxiway, but have to go all the way down, turn around and go back, which takes longer time. The controllers also listen to the aircraft's distance from the airport. By knowing this, it is possible to calculate when the aircraft is coming in to land. When the controllers hear an aircraft approaching, they know that the approach sector will soon call up for a hand over, and they start the preparations by lighting up the runway.

In the approach sector, the controllers listen to the tower to hear information about where the aircraft is in the departure process. That is interesting to the controllers for organizing their own traffic in the approach sector. Several controllers who work in the approach are also "rated" (licensed) for working in the tower and vice versa. That helps them to understand and use the communication they hear on the adjacent sector's radio frequency.

The method of listening in on the adjacent sector's frequency cannot be relied on for formal coordination. It is there to support awareness of the current state, reducing the amount of information that has to be communicated through telephone between adjacent sectors. If there were a lot of traffic, and therefore a lot of things to do, the approach sector would make an extra phone call the tower with an initial sequence of incoming flights. The controllers at Shannon ATC said that the system is unreliable if they are too busy.

When comparing the Copenhagen method to the Shannon method, one can see that they are the results of similar problems, namely information exchange through the time-consuming and obtrusive phone calls. The differences between these practices are an effect of factors such as the amount of sectors and traffic and are adjusted to the local tools and practices at each center.

The aircraft handover

When an aircraft goes from one sector to another the control of the aircraft has to be shifted from one air traffic controller to another. This is called a "hand over" (or communication hand over), and is performed through sending verbal messages over the radio. Between all sectors, including the approach area, these hand overs are being performed through the first ('sending') controller telling the pilot to contact the controller in the next sector on a specific frequency:

Controller A: "Scandinavian five niner eight call approach one one eight four five please"

Pilot: "OK goodbye"

The Pilot changes frequency on the radio, often by just flipping a switch on the radio where the next frequency has been entered in advance.

Pilot: "Scandinavian five niner eight, good morning, information Juliet, DC niner"

Controller B: "Good morning five niner eight, radar contact"

Once the pilot has called Controller B and s/he has answered on the new frequency, the aircraft is under B's control. A controller only listens on his or her own frequency[6], thus Controller A can no longer hear what is being said or take part of the conversation since the frequency is changed. Legally, however, the aircraft is A's responsibility until it crosses the sector border and enters B's sector, but in order to make the cooperative effort smoother they often hand over aircraft well before the sector border, as long as there are no foreseeable conflicts involving that specific aircraft. One might have thought that nobody would want to leave the control of ones own aircraft to someone else until one is 'in the clear' so to speak. But this way of working allows the receiving controller to handle the incoming traffic when convenient, which might not always be when the aircraft is at the border. In doing so, they have to be very confident that they can rely on the controller in the next sector to do a good job. One of the controllers expressed this relation between the controllers and the rules they follow as using ones 'flexible skills':

> "The safety first, of course, but also that… we have to, when we handle as many operations per day, to be flexible, to make it work, we can't just do it by the system, 'cause then it would be very rigid. /…/ The busier it is, the more you have to develop your flexibility skills, because otherwise it simply can't be done. If we would follow every rule there is, we wouldn't be able to handle the amount of traffic we currently are."
> (Tower/Approach controller in Copenhagen)

Another aspect of being able to hand over traffic in a considerable way, is that even if the rules state that the "hand over of control takes place at the border of the area of responsibility"[7] (the sector border) the controllers, at least socially, are responsible when they accept the aircraft from the other controller. A controller who can not hand over traffic in an efficient way is not a good controller, and might even not be considered trustworthy.

The following section summarizes the two papers based on the ATC studies.

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[6] In the approach control the W/N and E/S controllers each sometimes simultaneously manage two frequencies, one for departures and one for arrivals within their area. When they speak their voice is heard on both of their own frequencies, but the pilots only listen to their own (one of the controller's two) frequencies, depending on whether they are arriving or departing.

[7] Lokal ATS-Instruks TWR/APP, IV.

Paper A. The coordinative functions of flight strips: Air traffic control revisited

A key issue within CSCW is to describe and analyze coordinative artifacts. Such an artifact is the flight strip used by the air traffic controllers as representations of the different airplanes in the air sector that they manage. The strips contain large amounts of information, such as the latest flight level or altitude orders. These flight strips do not only work as a memory tool for the individual controller but are also relied upon as a resource for coordination. If and how this flexible yet locally situated information tool could be computerized has been a topic of discussion. In our example from Kastrup, the use of flight strips as a resource for coordination was further enhanced by the use of a CCTV system that broadcast the notes that an individual controller has done in her/his sector. What kind of affordance has a system like this and what does it implicate for the purpose of new design?

We derived a number of coordinative functions that the strips and the CCTV system fulfilled:

- The need to align the work in a sector to what kind of traffic will be coming in within the next minutes (and currently are located in other air sectors).
- The current system allowed for effortless coordination, i.e. the controllers did not have to do anything to coordinate the current situation in their sector.
- Some odd state reports could be entered by placing a message in line of the camera, such as "Vehicle on the runway"
- For the controller in need of information, the system was unobtrusive. The controller did not have to ask or call or disturb someone else when it was needed but could use it at the convenient time.

Based on what we saw in our study we drew the conclusion that there are ways to broadcast information in the flight strips and by studying a situation like the one at Kastrup we would get one step closer to capture how.

Paper B. Open audio/video links as means for coordination - two case studies

People are less prone to collaborate at a distance than when they are collocated. Although there are a number of fast and efficient tools like email and the internet, this remains a fact. Based on this, the question of what it is in the face to face meeting that is important for collaboration has been raised within the CSCW community.

An answer to this question has been labeled media spaces; continuously open video and/or audio links between locations. One such project was e.g. the Portholes, small video recordings on what is going on at a colleague's office across the Atlantic at the Xerox company. The media space projects have been interesting but have also been flawed on a number of reported problems; camera and monitor limitations; not having eye contact; not seeing what others see or point to; lack of privacy; lack of body language. The purpose of the media space is to give an informal yet coordinative contact to others and the examples I had from Copenhagen and Limerick fulfilled it without the problems reported. While Kastrup used CCTV to broadcast the state in a sector, Shannon airport used overhearing of the radio traffic as an informal resource for coordination of what is going on in another sector.

Broadcasting a focused view of key artifacts that are already in use locally showing the state of work is a successful approach for coordinating work. For many purposes it is a better approach than broadcasting a general view of the room and the people in it mainly because:

- participants get an appropriate amount of information
- it avoids confusion on what it is one sees on the monitor and what one can expect others to see
- the participants can choose by themselves when they want to use it, the system is not obtrusive
- privacy can be maintained through knowing what/what is not distributed by video/audio

This study shown that restricting the audio/video focus to a delimited part in the setting, and using these focused media spaces for distribution of the participants work, could be a successful way of effortlessly supporting coordination and awareness. A future direction for media space research could therefore be to explore focused media spaces] further.

ATC discussion and conclusions

Air traffic control is typical for centers of coordination. The work involves highly specialized skills as well as a large number of tools; some of them are described above. A number of different pieces of information are selected, juxtaposed, and acted upon. In paper B there is an example of the interplay between the controller and her/his set of tools that provide different kinds of information during the routine task of handing over an aircraft. This information is juxtaposed and compared and acted upon. The setting can be compared with an orchestra, where the controller is the conductor that synchronizes all the different kinds of information and keeps the pace. The way that air traffic controlling has been organized until now when the work is computerized, has been a quite tangible and embodied way of working, turning to different screens and colleagues, handling flight strips and their holders, writing down information, and so on. Information that is available 'at hand' and 'at a glance' is often mentioned as examples of effortless interaction with information and technology. In the case of air traffic control this relationship to technology seems to be a fundamental reason for the current success; the process and information source are transparent. The current setting puts the controller very much in command since it is s/he that puts it all together, rather than a computer doing it for her/him. It also enhances others' awareness of what is going on in the sense that the nearest sitting controllers can identify specific activities by the body posture of others and arrangement of the strips. The CCTV-system described in this chapter also to a large extent helps provide awareness of the continuously transforming state in a sector. The manipulation of the stripholders allows for specific kinds of coordination; the position of the artifacts is an indication that a certain flight needs special attention of some kind. This local articulation of work is transmitted in an elegant way to the adjacent sectors.

"Then they bloody well have to coordinate!"

The work is highly coordinative but since it is time-critical, the coordination needs to be effective. Coordinative situations can be divided into two kinds; the agreed routine situation vs. the exceptional situation. The routine situation (when the flight is moving according to the flight plan and the formal agreements between sectors) is handled with as little effort as possible; no talk and no obtrusive information exchanges between the controllers. The pilot just calls the new sector when instructed to change frequency to the next sector's. When the controller needs to make an exception to the plans and agreements, then the regulation states that s/he needs to do a verbal coordination with the next sector. At first glance this seems to a pretty clear division; however, what is "enough" out of the ordinary to generate a verbal conversation is not always agreed upon. We noticed several of these "near misses" or moments when the controllers got irritated at the colleagues lack of coordination. These ambiguous situations, that one of the collaborators experienced as routine and the other one as an exception, were probably due to several causes. One cause could be the visual display of the air space; the radar, that easily gets clogged with aircraft representations at certain waypoints during busy times in the approach sector.

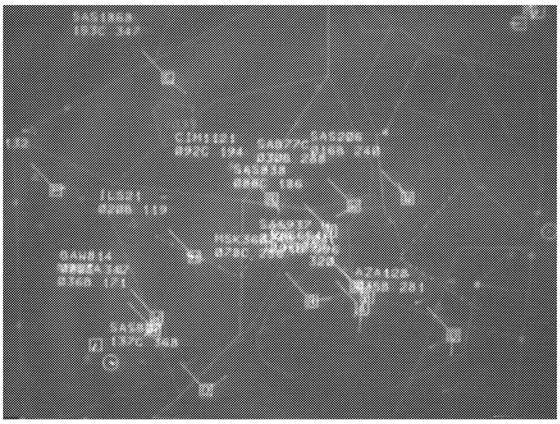

Figure 14: The constantly transforming airspace on the radar screen

The representations of the aircraft therefore work as boundary objects; when they are coming in the en route sectors they may be clearly visible but coming into the busy hub at Kastrup approach, they may be difficult to separate at a glance. Hence, another controller may experience the slightly different position as something the controller in the next sector obviously will see on the radar. Another reason may be that the controllers cannot always see each other's intentions with a certain organization of the air space. A good controller keeps an eye on what is going on in other sectors; it is part of the professional skills to look out for each other. But if there is a lot of traffic in the own sector, the controllers are likely to be less aware of what is going on in other sectors. Therefore, they might miss the reason for organizing the traffic in a certain way ("there was a slower aircraft in front"). There is thus a complex situation when on the one hand the controllers "bloody well have to coordinate" and on the other ""we need to reduce the coordination, because it takes to much time and is a source of errors" as one of the supervisors put it.

5. Field study results - SOS

SOS Alarm is the state-owned company responsible for managing telephone calls made to the emergency telephone number 112 in Sweden. SOS operators receive, categorize, document, dispatch and monitor the incoming cases. At larger SOS centers, a case is almost always coordinated between two operators, a call-taker and a dispatcher. The centers are equipped with computerized maps, maps made of paper, folders and a Computer Aided Dispatch system with a local database called CoordCom. SOS Alarm is (at the time of writing) developing a new computer system aimed at supporting the handling of different kinds of calls across the centers. In effect, this means standardizing the technology use across all the 20 centers and at far as possible standardizing work practices. Currently, collaboration between call-taker and dispatcher is entirely local. The new system, however, will allow for the emergency calls to be handled by any centre, e.g. the least busy one, though dispatch will remain within the local centre. In these circumstances, the distribution of knowledge now and in the future would seem to be a critical issue.

Operator skills

The logic of information-handling at SOS Alarm can be traced from the moment a call is received at an SOS centre. For the call-taker, the first issue to be dealt with is whether the call is an appropriate emergency case to deal with at all (bearing in mind the large number of hoax calls made, and other forms of time wasting), followed immediately by a decision concerning the priority to be attached to the call (based on how serious the case is, and how immediate the response needs to be. Priority is allocated on a 1-4 scale.). Following on from this, decisions have to be made concerning the relevance of incoming and outgoing information, and in particular who that needs to hear it and possibly act on it. This work is done while documenting and recording information and decisions in the CoordCom system. Operators often have medical knowledge, unsurprising given that many call receivers and dispatchers are ex-nurses and ambulance drivers. Other information that is recorded in the system will include the "where" and "who"; the address of the incident and who the ambulance should pick up.

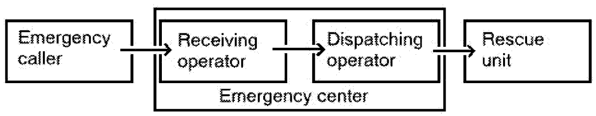

Figure 15. A general overview of the development in an emergency case

As soon as some basic information is entered in the CoordCom database, the ambulance dispatcher can start dispatching (if it is a priority 1 case) while the receiving operator can continue to collect more information about driving directions, development of the accident, etc from the caller. S/he chooses among the resources that are suggested by CoordCom, based on proximity to the ambulance station and a set of other conditions. After calling the ambulance verbally on the radio, the operator sends out a mobitex message, a text message that gets printed out in the ambulance, containing the case information that was entered into CoordCom. The mobitex system is also used to send automatic status reports from the paramedics to the dispatcher. The dispatching operator then follows the progress of the ambulance or rescue vehicle through these status reports. S/he may also help coordinate information between different vehicles.

The 20 SOS Alarm Centers in Sweden have certain security rules and regulations. Besides having an appointment, you need to be let in at the gates and then also let into the actual control room. There is a shift leader that is responsible for the operative work that handles guests. On agreement you are allowed to sit beside an operator and listen in to the incoming emergency calls, but you have to sign a professional secrecy agreement first. The control room is shelter classified and has large concrete blocks that can cover the windows. The centers differ in size. At the three larger centers there are 8 operators or more working at daytime while in the smaller centers there are 2-3 operators working together. The operators sit at positions equipped like in Figure 16 (it differs marginally between the centers):

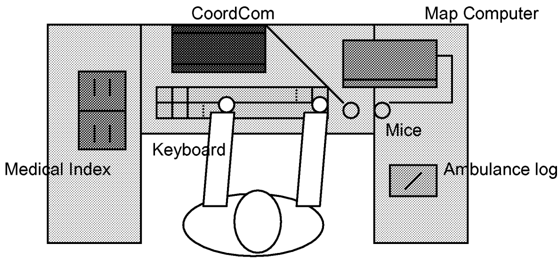

Figure 16: Malmö position

The operators' main tool is the computer-aided dispatch system called CoordCom. Through the system they handle all communication: telephone, fax, mobitex, radio. They also do all documentation in it. The system is connected to different databases, both the local ones: all action plans, ongoing cases, resources, contact information and also to a central database: the telephone subscription record that generates addresses from the caller. The CoordCom is handled through a specially made keyboard that has selected functions to suit the system, for example to answer a 112 call. There is also a mouse and the operators use a headset connected to the computer to communicate.

At some centers in Sweden there is a Map Computer in use as well. This computer is mainly used to track the units in the area through the GPS system in the cars. The system can also be used to look up addresses, but is usually considered to slow for that.

An incoming 112 call is answered with "SOS 112, what has occurred". That is the first thing the operator tries to decide. Is it a case for SOS or not? What kind of priority should be assigned to the case (1-4)? Do I need to ask a fellow operator to listen in to the call? As we will see from the Stockholm and Malmö cases, this division of labor is handled differently. While deciding what kind of accident it is, the operators work with CoordCom to document and label the accident. The second kind of information is the address of the incident. After putting in the address, a colleague can start dispatching (if the case is priority 1) while the receiving operator can collect more information about driving directions, development of the accident, etc from the caller. When the call is finished, it is the dispatching operators' responsibility to handle the case. S/he chooses among the resources that are suggested by CoordCom, based on proximity of the ambulance station. After calling the ambulance verbally, the operator sends out a mobitex message, a text message that gets printed out in the ambulance, containing the case information that was entered into CoordCom. The mobitex system is also used to send automatic status reports from the paramedics to the SOS operator. While the ambulance is turning out, there are several kinds of status reports sent. These are for example status U - we have received the call and are on our way, S - soon arriving, F - at the accident site, L - the patient is now in the ambulance. (The letters are the beginning of the Swedish words for what they are doing, e.g. U = utryckt.) The dispatching operator then follows the advancement of the ambulance or rescue vehicle through these status reports. S/he may also help coordinate information between different vehicles, but the dispatching and monitoring can be handled without any verbal communication between the operator and the units.

Tools and procedures

CoordCom is the computer system in and through which the operators communicate, monitor and document in the cases. It is the computer system towards which the operators mainly orient. CoordCom is handled with a specially made keyboard that gives direct access to certain functions (e.g. answering a 112 call). The database in which the cases are stored is local, i.e. each center has its own database and cannot access cases documented at other centers. There is no connection between the networks (the centers can thus not communicate data between themselves). The CoordCom supports all the different ways of communicating; through telephone, radio, mobitex (a text-based communication system used between the units and the SOS central and for automatic alarms), and fax. It also supports making records of the different kind of cases, both emergency and commercial alarm service, that SOS is handling. This documentation of the cases is stored in the local central today, but the idea is that all the centrals should be able to share the information and therefore be able to work on each other's cases in the future. The design of CoordCom is focused on the incoming calls. For dispatching and monitoring the ambulances and rescue units there is a "map computer" that shows the units with help of a GPS system that indicates where the ambulance units are on a digital map. This system is very useful both for giving driving instructions and to pick the ambulance closest to an accident.

The operators log in depending on the tasks they work with. By logging in the operators filter the information that they get. An ambulance dispatcher, for example, does not see the incoming 112 calls. The login is personal as well, so that each action is stamped with the signature of the operator that performed an action in the system (e.g. made a call or received status reports from the units).

Figure 17: The CoordCom with its special keyboard

The CoordCom interface is divided into two parts; the telematics part and the case part. In the telematics part all communication (radio, telephone, and text) is handled. In the case part, all information concerning the cases is handled. More about the CoordCom interface follows further on in this chapter.

Work description - incoming call

The ethnographic method with its interest in (work) practice in a certain culture, opens up for a range of different perspectives that one can take upon the work. The most obvious way to present the operators' work is to follow the development of an emergency case. However, cases are not handled sequentially but in parallel. This means that an operator works on a part of a case and then hands it over and begins with another case, even if the first one is not finished. This part thus does not describe the work process but the case development.

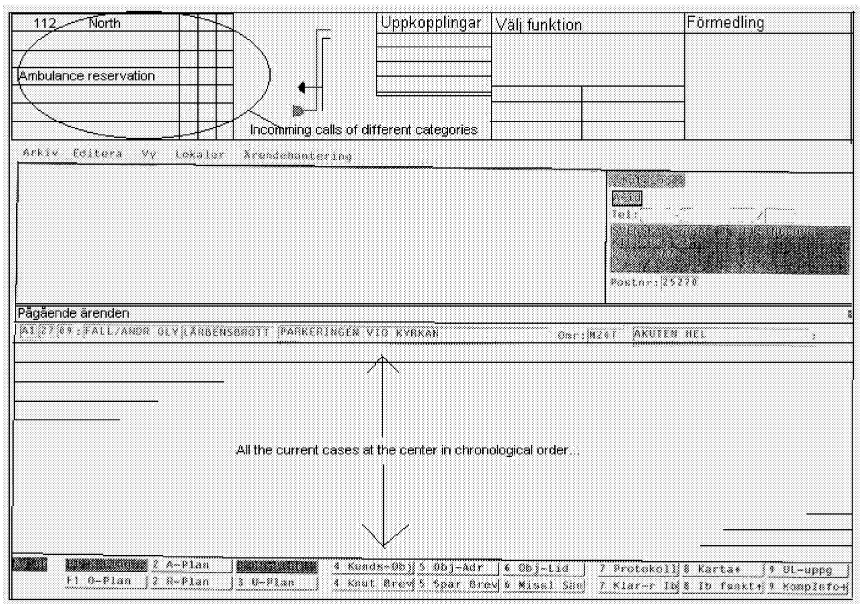

Figure 18: The incoming case view[8]

The upper part of the interface shown in Figure 18 is the telematic part. In the left corner, you can see a list of seven rows. These rows display different kinds of incoming calls or messages. This is how the calls are ordered (where no 1 is the topmost row):

1. Incoming 112
2. Co-listening requests
3. Automatic alarms (e.g. from elevators or fire alarms)
4. Calls to other numbers than 112, e.g. ambulance transportation ordering (no emergency)
5. Radio calls from e.g. ambulance drivers/paramedics
6. Mobitex calls
7. Transportation of calls, internal requests, time alarms (if the ambulances do not respond in time)

The symbol to the right of the incoming calls list represents the radio and telephone lines. They show e.g. if the phone call is put on secrecy or not. This does not seem to mean much to the operators, this is probably a remainder from the time when 112 (or the old number 90 000) was a switchboard service managed by the public phone company Televerket. Then the service was considered more as technically connecting to the right service (e.g. ambulances) than as a part of the emergency service. In the square next to the symbol the current connections are presented.

All communication made through the CoordCom is recorded and all

[8] The interface pictures in this chapter are based on screen dumps, which have been partly reconstructed and annotated by me.

information that is documented is saved in case it will be needed for later analysis of the case.

The call is answered by pushing a key on the keyboard. Then the oldest incoming 112 call will be chosen. The SOS operator usually answers "Ess Oh Ess one one two what has happened" (in Swedish: SOS 112 vad har inträffat). This practice has been discussed, as the phrase is sometimes confusing for people that do not speak Swedish very well. It is supposed to make people talk directly about the accident instead of beginning with polite phrases and personal introductions. While answering a call, the operator will have a basic view in CoordCom which includes a communication part on the current incoming calls, a so-called "Basic Form" (in Swedish: grundblankett) where the phone number of the caller is automatically shown, and a list of current cases at the central. At this point, a decision-making process starts.

The first decision to be made is, obviously, if this is a case for the SOS or not. Since the change of the Swedish emergency phone number 90 000 to the European number 112, there has been a high rate of invalid calls; prank calls, wrong number, calls aimed for the phone number information service 118 118, and so on. Since 112 is an emergency number, phone calls about for example a discovered break-in in a car (not ongoing) should be made directly to the police and not to SOS. Currently, SOS estimates that almost 80% of the incoming 112 calls are without a valid reason. Another reason for a high rate of calls is the mobile phones. An accident that earlier may have generated 3 phone calls may now generate 30 calls. This has been mentioned as a problem for the operators, both for the obvious reason that it takes a lot of time, but also since the operators say that they have "lowered their adrenaline rush" for the 112-calls and are more likely to finish a silent phone line quickly, since there are so many of them. (A silent caller might indicate serious problems and should be examined further.)

The operators may further check if the case is already recorded in the system in the current-cases list (the lower part of Figure 18). While I have been studying the operators, I have never seen a redundant dispatch, although I have seen a case become initiated five times in the current cases list. Due to the list and to overhearing, the operators seem to be able to coordinate current cases to avoid cases getting recorded more than once, it therefore works as a coordination mechanism that both structures and informs the coordination.

Initiating a case

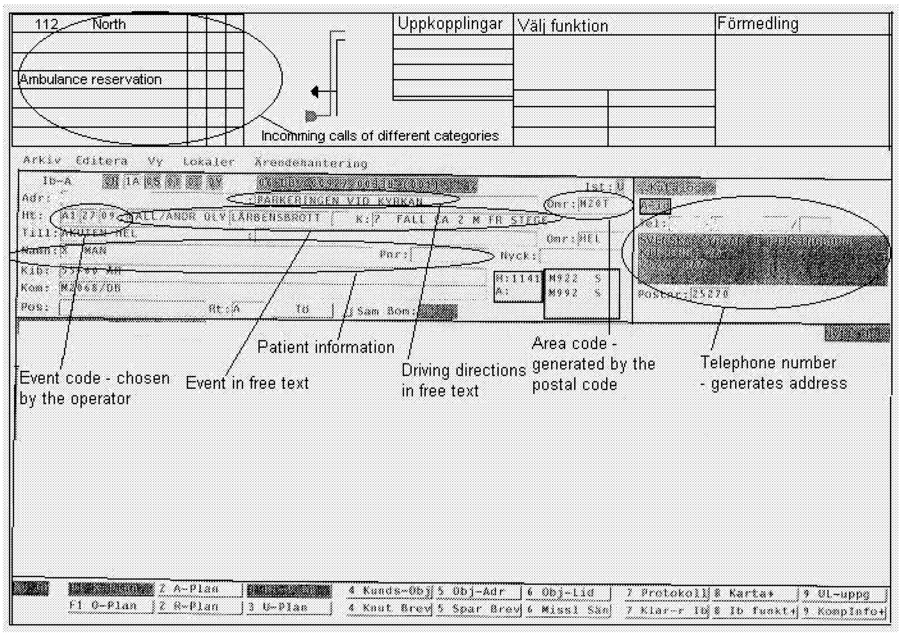

Figure 19: The case documentation

During the interview, the operator documents as much as possible about the incident. The first thing s/he decides is what has happened, then where. In doing so the operators choose an "Resource Form" (Swedish: InsatsBlankett) to work in. The Resource Form is one of 6 types: R=Rescue, A=Ambulance, S=Service, T=Traffic accident, L=Doctor, Y=Other, and becomes attached to the Basic Form. There could be several Resource Forms attached to the Basic Form. By choosing an Event code (Swedish: HändelseTyp), the operator decides priority and defines the type of accident. In order to generate an "Action Plan" (Swedish: HT-plan) from the CoordCom system in the case, the operator needs to put in what kind of accident it is and where it has happened. In Figure 19, the event code is A1 27 09. A1 means ambulance case, priority 1 (highest priority), 27 means "Falling/slipping accident" and 09 means "broken leg". This is specified in text as well. The operator further specifies what has happened by writing: "Fall, about 2 meters from a ladder". S/he also puts in a further definition of the place where the accident has happened; "The parking lot by the church". The area code is important, because based on it the CoordCom system will show a list of available ambulances in the area zone in question. It will not be shown otherwise. Usually, this code is generated by the address, which in turn is generated by the phone that the call is made from. The operator always has to ask about the address to make sure that it is the right one. If the call is made from a mobile phone, the operator gets no address and has to rely on the information given by the caller alone. In uncertain cases, the operators work with large paper maps where the zone borders are detailed. The map computer does not support this work.

How the dispatches are arranged is not decided by the operators, but by their "customers"; e.g. the different county councils. There are ambulance- and rescue officers in each county making general decisions for the dispatch order for each geographical area and type of accident. (If a fire occurs in C village, 2 fire trucks will be dispatched from A town and one ambulance from B city. The fire officer on duty in D city is to be notified). All these conditions are entered in to CoordCom and thus generate the Action Plan for each accident, which contains all the prespecified tasks that are to be done for the specific accident/location specified. While working on the what and where questions, the operators also write information about e.g. the person in question, earlier problems, driving directions and so on. All this information is entered in the header of the Resource Form.

Dispatch of the units

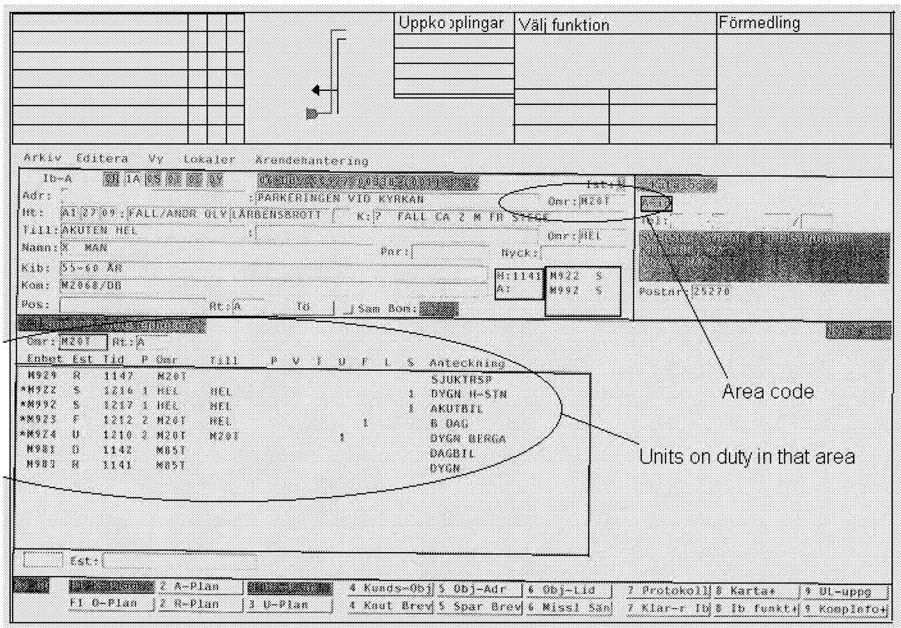

Figure 20: The area code generates the list of units in their area (and their current status)

In the view shown in Figure 20 the operator is looking at the list of available ambulances. Each row contains information about the name of the unit, its latest reported status, when that status was sent in, priority status of that specific unit, which area it is in and a note about the type and a description of the unit, e.g. "Day" or "Transport".

The policy of SOS is to start to dispatch the units at most 45 seconds after the emergency call has been answered in case of a priority 1 (life threatening) case. In order to be able to collect as much information as possible and/or give advice to the caller to help the injured in some way, the operators collaborate. It is likely in emergency cases that the operator that answers the call is working on another responsibility area. This means that the first thing the operator will do is to make a co-listening (or listening-in) request to the operator that is responsible for the dispatches in the area. In the case of a fire, there would be both ambulance dispatches for that particular area as well as collaboration with the rescue service. The co-listening request is done through the CoordCom, and as soon as the dispatching operator has acknowledged the request, she or he will show this by saying, "I am with you". In order for the receiving operator to inform the dispatching operator what the call is about, the operator usually repeats the information in the conversation to the caller e.g.: "so your father has fainted and he is not reacting when you try to shake him?". The dispatching operator can start to send out the units before the receiving operator has finished the phone call.

When the Action Plan is generated in CoordCom, it shows a list in priority order on what should be done. For e.g. a larger traffic accident or a fire in a major industry, there may be ten or more units/persons that should be notified. This takes quite a lot of time, and the operators help each other. The operators sitting next to each other usually overhear what is going on and if it is an emergency, the operators form temporal teams for dispatching and informing all units in the Action Plan. These teams are either initiated by the receiving operator asking "can you contact the police" or the operators around him/her volunteering; "I take the police". All the operators in the central have access to the current cases. In order to keep track of what has been done, there will be a time stamp in the Action Plan when a task has been done. The Action plans contain so called Logic Numbers for each task which are clickable and render a call or a sending of a mobitex message, etc. The first contact is made by radio. The operators inform the units briefly about priority, the kind of incident and where the accident has happened. After assigning a task to a unit, the unit has about two minutes to (sign in or) acknowledge the mission. If they do not acknowledge the mission the operators will try to contact them through mobile phone or mini call. The acknowledgement by the paramedics or rescue team, can either be done by contacting the SOS by radio, calling through the telephone or by sending a text message through mobitex. From the perspective of the operators, it looks like an incoming call containing a text message with the status of the unit. About the same time as the acknowledgement is received, the operator sends a mobitex containing the header of the Resource Form.[9]

[9] Possibly due to the relatively new mobitex system (about one year old) the operators often call the unit before sending the mobitex message or ask about it when the unit calls in. It seems to be important to be a bit redundant in the communication to make sure that information is spread properly to the units and to other operators. Another possible reason for (redundant) verbal communication may be to maintain goodwill in the relationship to especially the paramedicals, which the SOS has full delegation over.

Monitoring the development

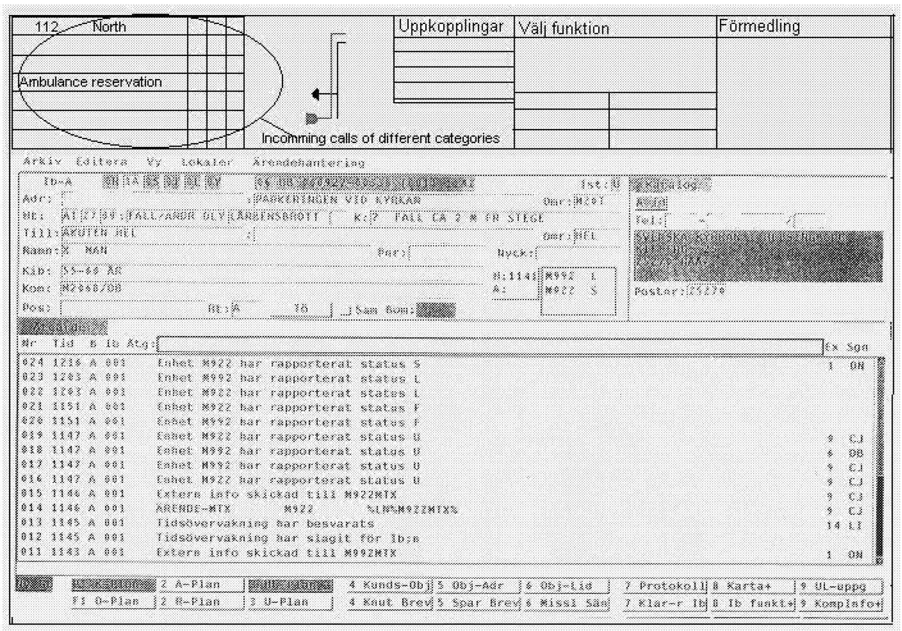

Figure 21: The events recorded by CoordCom in the measure list (below)

In Figure 21 the operator has opened the action log that shows all activities happening in the case according to the CoordCom system. This is e.g. when text is updated or added in CoordCom, e.g. if a driving direction is added. In the list above there is mostly the communication and status reports by the ambulances that are recorded. In cases which involve units of several kinds (both rescue units and ambulances) this list can be rather long.

When the units are sent out, the operator monitors the situation through receiving status reports, either through mobitex messages or through telephone calls. If several operators are involved, i.e. both rescue and ambulance dispatcher, the operators may communicate with each other the status reports that they have got. The unit that reaches the incident first will give a status report and decide together with the operator if the right service has been sent to the accident. All new information is entered into the head of the Resource Form of the case and is thus accessible to the other controllers. The new information may mean that new units are selected and dispatched in the case. It can also mean that some of the units sent are unnecessary.

In the monitoring work, the dispatching operator is working alone, but other operators may verify the status reports from the units. This may be because they want to find status reports aimed for themselves, and just verify the messages that are before in the incoming line. This does not seem to cause confusion as one might think, since the experienced controllers have a rather good idea of what the units are doing and how long time it is likely to take. But there are occasions when the status is not updated and a unit is sent out to a new mission without having the status Ready first. When the paramedics then acknowledge a new mission by sending in a status report, an operator not working with them may accidentally put their status as Ready (which makes the new mission be regarded as finished by CoordCom) instead of On The Way and cause some confusion.

The operators' task (among others) is to dispatch and make sure that they have dispatched suitable units. They are not responsible for the actual rescue, just to send proper units. This means that the operators usually do not get informed of the outcome of the actual incident. The case is closed as soon as the units have reported the status Ready (for a new assignment).

Two cases

The kitchen fire case

In this case I was sitting next to an operator handling fire rescues. The dispatch in the Malmö center is done in close collaboration with the fire department (which is located in the same building as the Malmö SOS center, a common arrangement). The decisions concerning rescue dispatch always have to be done in close collaboration with the rescue officers.

The call in question immediately caused the operator to make a co-listening request to the operator responsible for rescue cases that I sat next to. It was a rather simple case from the beginning. A woman called in that there was something on the stove that had started to burn and that she could not extinguish the fire. Her son was trying to pour water over it and the operator immediately instructed them to stop pouring water in order to avoid the water to come in contact with electricity. They were instructed to close the door to the kitchen and wait for the rescue service. While talking, the operator had chosen an IB-R (Resource form for Rescue cases) in CoordCom. A detailed driving instruction was written in the form. ("Drive past the big yellow house, turn left, turn right at the large stone on the left side, it is the third house on the left after the church.") She also put down the so-called map square number (which people living in the countryside often know for their house) to pinpoint their location. Based on the information put in the form, the action plan that was generated by CoordCom revealed that three smaller part time rescue stations were to be contacted. Since it was three different stations, there were also several people to inform. The action list that was to be done contained about ten different actions to be made. The operator sitting next to her helped the rescue operator. This was arranged spontaneously.

In order to find the house, the directions were extensively discussed with the different vehicles and units. There was also an ambulance dispatched, as is the rule at a fire in a home. When the first truck arrived, the whole kitchen was on fire, but three trucks were found unnecessary and one was instructed to keep on stand-by instead of driving to the accident by the first officer at the scene. The SOS operator distributed this information to the other units. Since there was no one hurt, it was also suggested that the ambulance could be sent back. The operator's role was thus not to make decisions, but to coordinate information between the different parties. She also connected the vehicles' radios so that they could coordinate directly. Her job was to make sure that the right service was there, a somewhat resembling an operating nurse at a distance.

When the fire was extinguished the operator was informed that the rescue team had had to make a hole between the floors to make sure that the fire was out in the roof above the kitchen. An elderly woman was also getting weak and an ambulance was sent for again. The woman did not want to go to the hospital and there was some discussion to and forth on what to do. It was only the practical issues, what connections were made and what resources sent, that were recorded in CoordCom system (besides from the fact that all conversation was recorded). The log of the case thus revealed rather little about the extensive coordination and discussion that the operator participated in.

In order to make sure that the family was all right, the rescue party stayed there and helped the family to contact the insurance company. As the hours passed by, the family got worried of being out of electricity, in particular due to their horse that was about to foal. If there would be no light in the stable, the family would have problems when trying to help the mare. This made the rescue officer contact the operator, asking her to call the closest fire station and request a power generator. The station was unwilling to lend out their power generator, since it was attached to one of their trucks. The operator then contacted the insurance company to ask them for help, which they could not come up with. Finally, the rescue officer and the operator decided that the family would have to manage, and the rescue party left and the case was finished.

The fever child case

The operator I sat next to was working as a 112 receiver, that is he only received 112 calls and passed them on to the dispatchers. The woman who called 112 presented herself as the nurse in the medical rescue boat that is stationed in the archipelago of Stockholm. She was with a physician who during the conversation examined a boy of 10 years old. The boy had high fever and the physician thought that there was some kind of stomach problem that was named in Latin. The question that the nurse put forward was how emergent this patient should be treated and how he should get transported to the Astrid Lindgren children's hospital. The 112 operator was not that familiar with the stomach problem that the nurse mentioned, so he did a co-listening request to the center physician in the opposite part of the room.

The physicians work at the Stockholm center at daytime, but while they are using the CoordCom to follow the cases and support the operators with decisions, they do not have any formal education on the CoordCom system. This meant that the 112 operator had to follow the conversation and enter the decisions that the physician took. In order for the physician to help the operator collect the right information, he walked from his position to the 112 operator. The physician was using a cordless ordinary phone (as opposed to the ordinary headset). The nurse at the other end had turned over the phone to the archipelago physician at the sick boy's house. The two physicians then discussed over the phone while the SOS physician stood next to the 112 operator (who was still co-listening). The question was; is the boy fit enough to take the ambulance boat or should they send the rescue helicopter? They decided that while the boy might be fit to go by the boat (which took longer time) he should not have to suffer the rather bumpy ride over the waves. The helicopter would pick him up (and therefore the case got priority 1). After this decision was made, the 112 operator continued to talk to the nurse that collected information from the boy's parents on where the rescue helicopter could land. When the call was finished, the 112 operator did a co-listening request to the dispatcher (who dispatched not only ambulances on wheels, but boats and the helicopter as well). While talking on the intercom (through the CoordCom system), the receiving operator explained the specifics of the case, she suddenly unplugged her headset and walked over to the dispatcher to explain the helicopter landing details. It was not a map that needed to be coordinated, which might have explained the receiving operators' need to walk over to the dispatcher. Instead, my interpretation was that the receiving operator wanted to give a longer explanation and she did not want to occupy the dispatcher's headset with their conversation. When talking outside the headsets, the dispatcher was able to communicate with the 112 operator in the room, while using the communication system to dispatch the helicopter.

Field study conclusions

One general conclusion that was drawn from the field study is that the system handles facts well. Facts are, however, not independent of the context. Personal impressions, judgement and local knowledge are important and unconditionally a part of the SOS Alarm operators' work. The computerized system should be considered as a communication and information storing system. It should not account for categorization and analysis of the case. One conclusion drawn from that is that the case files, as they were observed, are not complete. They lacked important information, conditions that were not considered as facts and therefore not entered into the system. There were some cases when the information in the system was sufficient, but in many of the cases, the operators had to coordinate verbally. There were no cases in the study where the verbal coordination was a problem, but considering the future setting where center-to-center coordination will be allowed, there verbal coordination may be more problematic.. One of the main potential problems was believed to be the time constraint. When the operators needed to coordinate verbally, they could facilitate the interaction through seeing what the other one was doing. They had overview of the current situation at the center and the actions of others. This would be more difficult, but not unsolvable, in a distance coordination arrangement. The goal is not to remove verbal coordination, but to consider when it could be replaced by a more nuanced case file information.

The account of the work of the receiving operator and the dispatcher and the CoordCom system gave several different results. The system was founded upon two older tools, namely the old switchboard and a paper form. The interface was thus not effectively used; the operators worked with only a part of the screen so that the full potential of the interface was not used. The form-oriented documentation part called for keeping the information short, too short for some occasions. The system's categorization method was based on a relationship between the priority of the case and the type of injury that the person in need had. This was often worked around since it was not only physical facts but conditions of the caller (is s/he for example vague or upset), the context of the accident (was it a public place), the age of the injured, and many other reasons that decided the priority. Also, in rescue cases, it was only the facts and not the underlying reasons that were documented. If this design would be maintained, there would be a potential problem when cases are supposed to be coordinated between centers and this important information would be lacking.

Paper C. Sense-making of an emergency call - possibilities and constraints of a computerized case file

The assumptions that underlie the design of the current emergency dispatch system do not always reflect the reality. One such assumption is that cases are straightforward and can be categorized by one label, e.g. chest pains. My studies have shown that in most cases there are a number of ambiguities that surround the situation that the emergency operator takes into account when deciding what kind of help that is needed.

In the larger control centers, such as Malmö and Stockholm, there would be two operators handling the case; a receiver and a dispatcher. The receiver answers the emergency call and decides what kind of response to give and which priority the case should have. The dispatcher manages the ambulances in the given area based on a set of rules; e.g. no area should have to wait longer than 15 minutes for an ambulance; no geographical area could thus be completely emptied of emergency units. The division of labor between the call-taking operator and the ambulance dispatcher raised the following issues as areas of concern. The call-taking operator needs to

- Make decisions about priority and be sure that the dispatcher understands the decision.
- Document the case on a form-like computerized case-file which has a very limited space.
- Be able to motivate the decisions to the dispatcher
- The dispatcher needs to grasp the background to the decisions so that s/he is sure of them
- Maintain a good relationship to paramedics, so that they are not dispatched when not really needed

The paper presented several examples of situations where the case file was not a sufficient resource for coordination of case decisions that lead to the following conclusions. The interface is not fully used; the operators work with only a part of the screen.

- The operators do coordinate issues verbally that are not entered into the CoordCom system that is their main data base system.
- The circumstances of the case are as important as the conditions of the injuries when the operators decide priority.

The form-oriented documentation calls for keeping the information short, too short for some occasions. The case categories in the system are based on a relationship between the priority of the case and the type of injury that the person in need has. This is often, as this study has tried to show, worked around since it is not only physical facts that decide the priority but conditions of the caller (is s/he for example vague or upset), the context of the accident (is it a public place), the age of the injured, and many other reasons.

Paper D. Local expertise at an Emergency Call Centre

While paper C was concerned with what the operators do to account for their decisions in a case, this study is concerned with locality, both cultural and geographical. The background was the new system that is developed that (at least in theory) will allow for emergency calls to be received at any center and coordinated between centers to the one that is responsible for the area in question. The receiving operator may thus be situated in another area. What does this mean and what situations concerning local knowledge might need support in the future system?

Geraldine Fitzpatrick (2003) has shown in her research how people find out "information in the small" through ad-hoc encounters; such as finding an interesting print-out in the printer. In a time-critical activity such as emergency dispatch, there is no time for browsing a print-out, rather the operators have to adjust their informal knowledge exchange. If you ask a colleague for information, that person cannot refer you to a book or a web page, but have to make the effort to provide an exact answer. The collection of information does thus not only require the requester of information to be active, but also that the provider of information adjust it in such a fashion that it can be used immediately. This is what we propose to call *combined expertise*.

The case presented in this paper is a description of a childbirth with several resources involved and some requests and changes managed. It gives an example of the combined information exchange. We try to show how, in our review of one extended case, certain background features define and limit the properties of expertise sharing in this environment. They are firstly that knowledge must be accessed relevantly, quickly and accurately. Of course, this is directly related to what kind of knowledge will turn out to be relevant. Secondly, that in some instances and regardless of the fact that cases are given different priorities at the outset, knowledge relevance is constructed by ongoing determinations of the urgency or seriousness of cases. Thus, the relevance of knowledge is, as suggested, emergent. Thirdly, knowledge is socially distributed. It is not typically held by one expert and by one expert alone, nor can one assume equal levels and types of expertise across all parties of the encounter.

It is not only general sharing of information that constitute knowledge exchange within the SOS Emergency Centre, it is the combination of (at least) two people adjusting and combining their knowledge; one looking for knowledge, the other one providing it in a suitable and convenient form that meets the time-limited conditions.

We also discuss some design implications for a new system.

SOS Alarm conclusions

The case transformation that the operator's manage and control is orienting the properties of the complex unique emergency situation towards the preset categories that formally constitutes "an emergency". It is very much a process of selecting, filtering, ordering and summing pieces of information and representing the accident in ways that make sense in the emergency dispatch setting.

Information is juxtaposed on the screen and it is hard to follow a skilled operators use of the system because they flip between different screens fast to compare different bundles/selections of information with their information at hand. For example; is the incident at hand already reported on and if it is, what can be told about the development. One part of the screen (the case file) remains the same while the lower part changes and shows the new information. At larger SOS centers it is difficult to hear what others are talking about, therefore the flipping and juxtaposing of information is also a way to maintain an awareness of what is going on at the center and if it is any larger incidents to know about. Another way to provide an awareness of upcoming cases as well as to articulate their character is the request of a listening-in. The listening in function allows the dispatching operator to get an impression of the incident as well as to add questions that s/he considers important to know in the dispatch process. S/he can also start to dispatch while the receiving operator collects more information.

This work is heavily tool mediated, but the tool, in this case CoordCom is rather rigid from a coordination perspective, the only tools for coordination is written text or verbal coordination, there is no possibility to highlight notable pieces of information. There is also no possibility for the operators to comment things through written text, there were one example when the receiving operator were supposed to explain where the ambulance helicopter were supposed to land but since the explanation would be rather long, she realized that it would occupy the dispatcher's possibility to talk to the paramedics. She thus chose to plug out her headset and walk over to the dispatcher and talk to her directly instead.

Comparison with ATC work

ATC and SOS work have several obvious similarities; they are linear, time-critical, safety-critical and thus organized around a large set of rules and regulations. The idea is to make the work as predictable as possible in order to reduce misunderstandings and confusion. Both workplaces have connections to the Swedish Defense and have been influenced in the military tradition of organizing work: practice should be predictable and sense-making; obvious to the next person that man the work position. By organizing the work according to certain well-controlled principles, what is commonly known as the "human factor", i.e. the mistakes and incorrect decisions taken by the users, should be reduced. Often, this underlying thought of applying a limited set of principles works well. When there is an obvious and easily categorized life-threatening situation such as an unconscious person with heart problems, there is no question about how to categorize and prioritize the case. But relying on principles, pre-defined categories and types inevitably means that borders and limits exist; where a situation passes on from being of the x-type to being of the y-type. Since the possible circumstances in the kind of work described here are virtually endless (especially in emergency dispatch), it is not possible to pre-define every situation and every choice. This means that although many cases are clearly of the x-type or the y-type, there will always be cases that viewed upon from different angles, *look* like either x or y. There will also be situations that, when applying the categorization principles, will be defined exactly in between category x and y. These gray zones in the categorization work are essential to be aware of when designing for centers of coordination. Arguably, many of the mishaps and incidents that today are labeled due to "human factor" are really due to the underlying system design; predefined categories and principles that the users are instructed to apply. Categories may be very well defined and delimited, but the bits and pieces of information that the controllers and operators in these settings are provided with and judge from, may not always be.

Distributed work

One of the aims of this thesis is to explore the relationship between collaboration and collocation vs. distribution. In order to understand the differences between collaboration in these two settings, it has during my studies become apparent that "distribution" needs a more elaborate definition. The general assumption is that collocated work means when the participants are within seeing and/or hearing distance from each other. In order to think of ways to support a distributed setting, the implications needs to be explored further. My studies suggest that collocation indicates common local knowledge of the immediate geographical area as well as knowledge of common practice. The air traffic controllers, for example, were collocated in the same room but not always in visual contact. On the other hand, they had the same local knowledge of the Danish airspace as other controllers in the same room. Local practices might on the other hand differ slightly between the different kinds of controls (tower, en route control, the approach). This suggest a more complex concept of "collocated work":

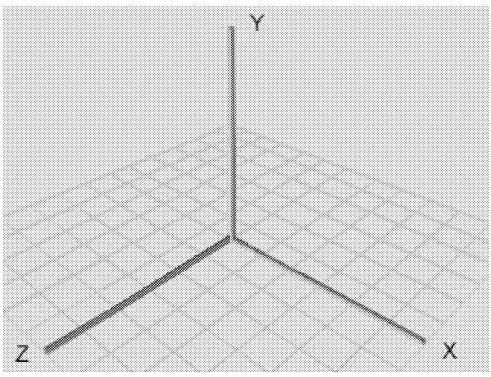

Figure 22 The components of collocated work in relation to distributed work
- common local knowledge (x)
- common physical space (y)
- common practice (z)

This becomes especially clear in the SOS setting, where center-to-center case coordination is in question. I focused on practice and local knowledge as two different issues, although they may be closely intertwined; knowing that "we usually dispatch a helicopter to the islands in the archipelago so that the patient does not have to endure a bumpy ride in the boat" is such an example. But in other cases, for example in air traffic control, one might have specific local knowledge of the center; important waypoints, runways and so on even though the specialized practices in another part of the center might not be clearly transparent. At a certain detailed level, awareness of each other's practice becomes irrelevant, but as shown in earlier studies of boundary objects, it is important that participants are aware of what kind of information another sector needs to use in their work.

Paper E. Transforming field observations into functions - on the use of an ethnographic study in the design process

In this paper the first attempts at using an ethnographic study as the design material is described. It is an example of how the findings and reflections from the study could through a number of steps be transformed into a requirement specification and finally a prototype.

It is well established that ethnography is useful for understanding professional practice and concerns from a situational, actual perspective (Plowman et al., 1995; Schmidt, 2000). It is also established that many applications fail or are worked around since although they may have the right components, they fail to match the actual accomplishment of a task from the perspective of the user. While computer systems aim at supporting professional practice, the obvious conclusion drawn is that this kind of understanding could be useful for successful system design. The last project aimed at making a prototype based on the reflections made in the ethnography during the study at SOS Alarm but also based on other reflections made in centers of coordination in general. The main motivation was to explore the possibilities to use the ethnographic material as foundation for design.

The question of how to use the ethnographic approach and its often-related theoretical perspective ethnomethodology in system design has been addressed from several angles. Ethnomethodology (see e.g. Garfinkel, 1967 or Coulon, 1995) within the CSCW context implies a general focus on the every day methods people use to display their intentions to each other and how artifacts of different kinds shape, support and limit these displays. Button and Dourish (1998) suggest three alternative approaches to integrate the ethnographic/ethnomethodologic perspective within a system project (what they call technomethodology);

- Learn from the ethnomethodologist by working together in the project.
- Learn from ethnomethodological accounts of work's social aspects in general and artifact use in particular
- Learn from foundational ethnomethodological principles such as accountability, situatedness, etc. that all concern our need to display intent, either through body language or manipulation of tools.

This study's contribution to the discussion of ethnography for design (further discussed in paper E) is practically oriented but takes on a slightly different angle; how to use the ethnographic observations when continuing with the system observations. The question is therefore how to translate the ethnography into functionality. The ethnographer thus moves on to becoming a system designer. We wanted to explore whether the ethnographic material in itself could be transformed into a design. In our explorative attempt we used seven steps

- finding the process to support
- looking for goals and concerns
- looking for limitations
- formulating requirements
- conceptual sketching
- interface scenarios
- final implementation

This is obviously not the only way, or necessarily the most effective way to conduct a design process. On the other hand we have kept a close contact with our original material and functionality in the implemented prototype and we can refer to the original observation.

Using ethnography as a basis for design is sometimes defined as a practical problem. In many ways it is, but, that does not mean that it is a simple problem. There are challenges in the shift of perspectives between starting as an ethnographer and moving on to become an intervener and designer. There are also challenges in the shift from the work process oriented format, towards concepts and their properties. In this project we faced these challenges by taking small steps, which all were guided by the work process that we went through in relation to the current design material many times.

Prototype description

The prototype we developed was a web-based database system that could be used for prototype testing. It was delimited to medical emergencies. The user logs in by choosing type of operator (receiving or dispatching) and what center s/he will be working for during the session. Our idea, based on what the SOS Alarm had suggested, was that an operator only works with cases at one center at a time. The center can thus become distributed, consisting of operators located at several centers but all of them are logged in on e.g. the Stockholm center. The prototype further supports receiving and documenting a call; when a call is "answered" in the system, a window with the telephone number of the caller and, if available, address information is shown. The operator can then choose to add the caller either as "Caller" or "Patient", depending on circumstances. This action opens a new case file that the operator continues to fill in. If the caller and the patient are different persons, the operator can add more information later on concerning the caller ("wife instructed to do CPR" or "neighbor will look out for the ambulance").

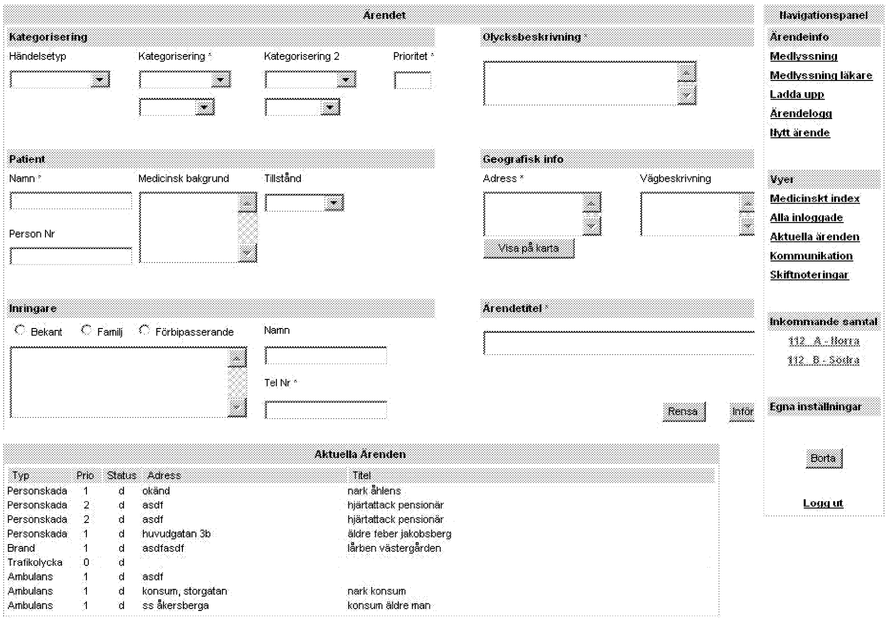

Figure 23: The EmCoord case file to the right, the menu to the left and Ongoing cases below

It may seem like much information in one screen, but as has been noticed in my studies and in other studies of time-critical work, information is often juxtaposed and interpreted in the light of other information. Our idea was that the users should be able to expand and condense the case file based on the need for information.

Under the address area there is a button "Show on the map". Addressing the local knowledge issues discussed in earlier sections, the map should not only include geographical information, but also hospitals, local nick-names etc. A further function addressing local knowledge is the (rudimentary) Center map over the center that the operator is logged into.

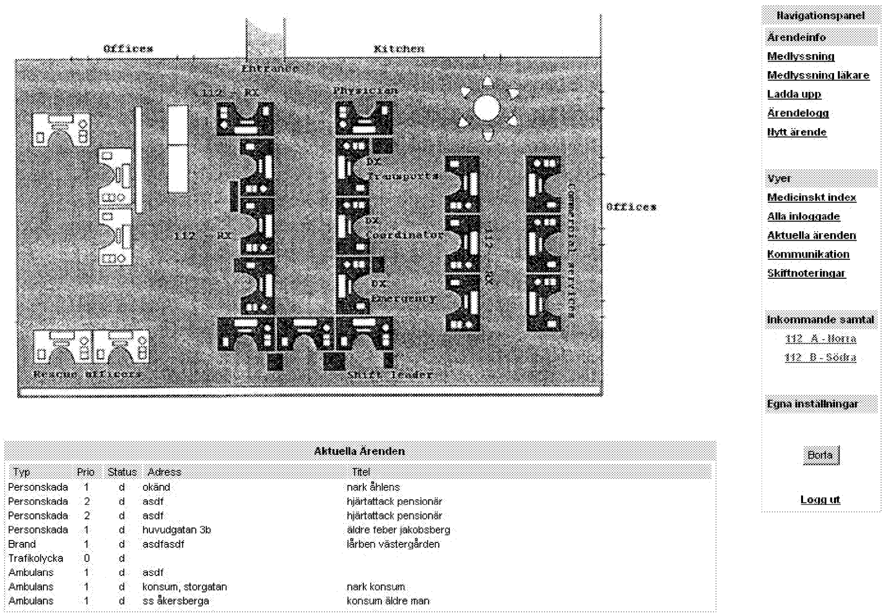

Figure 24: The Center map of the center that the operator is logged into

When the operators are sitting in the same room they can maintain an awareness of the availability of others; if someone has e.g. temporarily left their seat. It is not customary to log out if you go to get a cup of coffee. But when people are located at different centers they obviously cannot see each other. We addressed this problem by adding the Away button (below the menu to the right). When this button is clicked, the desk that represents the operator shows it. To support local knowledge, we implemented a function called Shift notes, where the shift leader would be able to add major incidents or temporary information in relation to the area. Finally, we prepared for a chat function, Communication, which would allow the operators to discuss cases without having to discuss verbally with each other. Talking is not a problem but it blocks the operators' possibility to talk to other services, especially to dispatch ambulances.

6. Discussion and conclusions

In the first chapter, I characterized the nature of the issues in this thesis as snapshots of processes that are in transformation. These issues were for example the state of the domain; the technology support; the work practice; and bringing new design based on these insights. A reason for viewing these issues as transforming is the method, ethnography, that aims at describing the course of events rather than laying them down. The benefit of viewing the research issues as transforming in this way is that it requires an attention towards what conditions and properties that allows for, and hinders, their transformation. What is required for emergency call notes to be able to transform them into a basis for selecting which ambulance unit to dispatch? Or what is required of local information earlier available in the room be transformed into information suitable for a distributed setting? And, what part of an ethnographic observation is needed in the process of transforming it into a basis for design?

The questions that this thesis proposed to examine were how technology, work practice and coordination are related to each other and how these insights could be used to inform design. The domain in question, centers of coordination, provides numerous situations for insights in distance and collocated collaboration and technology use. There are a number of situation specific observations that can be linked to earlier research; these were presented in chapter 4 and 5. The papers focus on four issues in relation to coordination and technology:

- Coordinative work practice and implications in using video/audio in a distributed setting (paper A & B)

- Support for accountability in decision-making in a distributed setting (paper C)
- The role of local knowledge and combined expertise in a local collocated center (paper D)
- The transformation of ethnographic observations in the design process (paper E)

These issues became of interest against the background of the exploration of coordinative work and technology. The following sections will recapitulate the conclusions on these topics.

Relation between work and technology

The work in centers of coordination described here can be characterized as the time-critical management of an outside world that is constantly transforming, possibly into life-threatening situations. It is in other words a very demanding kind of work. The results of my research in this area to a large extent prove the saying ”in theory there is no difference between theory and practice but in practice there is”. In theory, the air traffic controllers are responsible for managing their own air sector but in practice, they are more ”globally” oriented and keep a constant eye on what happens in other adjacent sectors. They are concerned with how their own air traffic can be adjusted and integrated in a suitable way to the overall situation. In theory, the SOS operators are interchangeable and an emergency phone call can be dealt with by any Swedish SOS operator without any familiarity with the local setting or the dispatching colleague. In practice, the operators mangage and negotiate a lot more than the formalities require and are depending on each other’s local knowledge. Arguably, this difference between formal and actual work practice really needs to be acknowledged further and should not be ignored when designing new successful systems.

The relationship between people coordinating through and interacting with tools is complex and can be analyzed from different perspectives. A basic assumption is that tools mediate coordination in many different ways; one being the mere alteration of the tool, like for example the ”do not disturb”-sign that hanging on the outside of a hotel room door affects the practice of the cleaners. It is the context and the actual placement (on the door knob) that creates the coordinative effect. One important focus in my studies has been coordination mechanisms and how coordinative intent can be articulated in a given setting. As many studies have shown, a collocated setting gives more possibilities to articulate certain conditions (i.e. manipulating common objects) either to show the state of work or to show circumstances that are out of the ordinary. Typically, in a proximate situation, the participants use body language and talk to account for their situation. They may also manipulate tools by positioning them in certain ways. In air traffic control and emergency centers, the possibility to see or hear colleagues ”in the room” is restricted by the large number of tools that surrounds them. In air traffic control, the strips is an object that is transformed along with the status of the aircraft, not only to keep data but also to show discrepancies and potential conflicts. My studies show that the practice of articulating the nature of the situation at hand is very often used and if the technology is restricting this possibility, the informants will work around the technology.

Another earlier reported important aspect of coordination and coordinative tools is the possibility to maintain an awareness of others activities and a number of such functions were found both in ATC and at SOS. In both ATC and SOS work, the professionals deal with the control of a constantly transforming external setting. When doing their part, they must keep in mind that others will have to deal with their decisions and the ordering of their work. They also have an interest in what kind of tasks that are coming into their responsibility. In the case of ATC, the overview of what the situation is in other sectors showed to be an important part of the work. At SOS, the overview of ongoing cases and the availability of others are two important aspects to be able to be aware of as an operator. My studies show that the informants often take the opportunity to check what is going on in other parts of the center. Maintaining awareness is a large part of the work in centers of coordination.

Typically for safety-critical work there is a need to juxtapose and match different kinds of information from different sources. In ATC this becomes clearly visible since the controllers work with a large number of different kinds of screens and tools that provide information. The controller collects several pieces of information on her/his work desk in order to match them and take a decision on how to order the airspace in the most useful way. At SOS, the system can be divided into computerized and non-computerized sources of information, the computerized source is largely focused on one screen that the operators are very skilled in reordering depending on what kind of informations they need to match. Although the computerized system allows for large amount of information storage as well as broadcasting of information very fast, the one-screen display is somewhat restricting in time-critical work. It does not allow for the time-saving information overview that the ATC work desk provides. Since many studies besides my own have shown that the juxtaposition of information is an important character of complex work in centers of coordination, there are reasons to consider this issue seriously for new design of this kind.

Defining distributed work

One of the aims of this thesis is to explore the relationship between collaboration and collocation vs. distribution. In order to understand the differences between collaboration in these two settings it has during my studies become apparent that distribution needs further definition. The general assumption is that collocated work is when the participants are within seeing and/or hearing distance from each other. In order to bridge the lesser quality of distributed interaction with design, the concept needed to be explored further. My studies indicated that collocation also implies common local knowledge of the immediate geographical area as well as knowledge of common practice. This led me to formulate the following picture of "collocated work":

- common local knowledge
- common physical space
- common practice

These issues, consequently, suggest that a system aiming at supporting distributed work should provide support for not only the lack of the common room, but also knowledge about the local setting and their local routines and practices.

Using video/audio in a distributed setting

The study of air traffic control gave a successful example of support for distributed coordination, namely the use of video and/or audio for distributing local information. The study showed that the successful coordinative functions of the CCTV-system in ATC was to a large extent relying on the provision of information *when required*, and the system was adapted to let its user decide when the information was needed. It was also *adaptive* in the possibility to provide information; information could be highlighted and transformed in order to provide attention for other users. The users could also *add functionality* by providing other kinds of information (e.g. a strip saying "Vehicle on the runway" when there was a delivery truck on the runway). Based on earlier research in the area of video/audio links as a means for providing awareness elsewhere, I related the findings in air traffic control to the problems earlier reported; issues on privacy, usefulness, technical limitations etc. These attempts have often been directed towards providing a general overview of a room and in consequence concerned with what is an appropriate view to broadcast. My studies showed that the ATC case did not result in confusion about what was seen on the screen/heard on the radio, or how to manage private and public spaces. This led to the conclusion that a focus on the *object of work* rather than individuals is a possible and useful road to explore in the future for supporting distributed work through open media link.

Accountability of decisions

The operators at SOS Alarm often discuss the background and the reasoning behind decisions verbally. The endless variations of SOS cases cause a need to understand more of the background to the decisions than is included in the current CoordCom case file. Not only is there a need to discuss the basis for a decision but there is also a need to mention circumstances that affected the categorization of the case. Decision-making in such a varying kind of work as emergency case handling sometimes requires explanations. My interpretation of why motivating decisions was important was because the dispatcher has a limited set of resources and s/he will have to answer to the paramedics if the ambulance unit is unnecessarily dispatched. Judgment is questioned because the current case file does not include circumstances that are taken into account when categorizing the level of emergency in a case. A broken leg at home and a broken leg in a public space can for example be prioritized differently because it is considered more awkward to be helpless and injured in public display. In the EmCoord project we suggested a more elaborate case file, for example we thought that there should be a separation between the emergency caller and the person in need of help ("father seemed freaked out"). We also added medical history ("had a stroke this spring") and a larger area for adding information about the case. Allowing for the account of underlying reasons for a specific decision is crucial in case coordination.

Local knowledge and combined expertise

The work required in centers of coordination, although geographically collocated, is often distributed in its character; the actors are not always able to leave their position where they might not have visible or auditory contact with others. Exploring the dichotomy of collocated-distributed work leads to questions about how to coordinate at distance but also what to coordinate. The background of SOS Alarm's new system, where center-to-center coordination would be allowed for, it became even more interesting to examine the role of *local knowledge*. A number of issues emerged; local nick-names, famous places, the location of important buildings, etc but also the expert knowledge of having been in the mall or driven at the motorway. Local knowledge at SOS Alarm does not only come from working in the area but also living in it.

Within the area of knowledge management, questions about shared expertise have been raised. Shared expertise is founded in the local setting based on what one knows about one's colleagues. The chapter by Fitzpatrick (Fitzpatrick, 2003) gave examples about the ad hoc collection of information through finding interesting printouts or books at other people's desks. In office work, knowing who to ask and who can suggest where to find information on a given topic is a suitable level of expertise sharing. But time critical settings do not only require knowledge about who knows something about a given topic, but also knowing who can provide the information, the exact answer that is needed at once. The sharing of expertise therefore does not only require efforts of the person requesting information, but also of the person providing it. This is what we suggested to call *expertise combining.*

A note on categorization

Accounting for underlying reasons when categorizing situations is, as mentioned above, a sometimes overlooked issue in centers of coordination. Many misunderstandings can be derived from a lack of knowledge about the conditions that a decision was made upon. This problem, arguably, stems from a belief that interpretation can be automated by rules and regulations. Coordination cannot be deprived of ordinary social needs, such as when uncertainties occur, one tend to prefer to judge the situation for oneself. Bowker and Star (2000) have as discussed in this thesis examined so-called *boundary objects*. I would like to add to their theory that in the case of centers of coordination, there is not only a need to see the perspective of others when interpreting information but one should also conider the conditions that contributed to the selection of a particular piece of information. The disregard for the wide variety of categorization work in the settings described in this thesis is what I believe to be the main reason for problems and constraints in the current coordination work. In emergency dispatch there is an extensive folder about how to categorize physical symptoms, but as examples have shown in this thesis there is no rules to use when dealing with a desperate father or an injured woman that is worried about her runaway dog. It is obviously impossible to give instructions on such varying conditions, but they are a part of the work and disregarding them in the case file design may create a large number of problems.

Ethnography as a resource for design

A question that has intrigued me since my Ph.D. project started is why it seems to be so difficult to make use of ethnography in the design process. As a finishing project I wanted to explore if and how it could be done. This project is practical but also a bit controversial because it inevitably reduces the richness of the ethnographic account into pieces that do not include anything about the ethnographer's intentions or selections.

Arguably, being a practical problem does not make it a simple problem. Knowing how a practice is performed today does not give away any suggestions on how the technology that supports it should look like. It is therefore important to investigate how a given activity is *related* to other activities. It is through knowing how different activities are related to each other that it is possible to imagine solutions for the interaction design. Deriving relationships between activities and objects in an ethnography is what I consider the main challenge when using ethnography for design.

The work process that we used in order to transform the original ethnographic material into design was

- finding the process to support
- looking for goals and concerns
- looking for limitations
- formulating requirements
- conceptual sketching
- interface scenarios
- final implementation

The ethnographic study as such is a somewhat controversial method in system design. It is time-consuming. It does not in any obvious way help to derive how the new system should be designed. As I have shown in the research on ethnography for design, deriving functionality and knowing how to order functions based on the ethnography is a possible road for making use of ethnographic studies. A starting point like the one in the ethnographic studies in this thesis; professional skills as the motivation for action and ordering the work; adds information to the traditional user study with a focus on what the user wants to do. I believe that this is a possible road to take and I welcome further descriptions of ethnographic transformations.

Further work

The continuously developing (transforming!) computer possibilities and the fact that a very large amount of professionals have integrated computers or computerized tools in their skills makes it important to explore the actual practice and use of tools and to find better ways to involve such studies within the design process. There is much work to be done in general in the area of coordination and tools, especially how to design coordination at a distance so that it at least becomes as rich and flexible as the face-to-face situation. But as the thesis has shown, and what I believe should be much further researched, the distributed setting needs much more specific definitions.

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