IT IN HEALTHCARE

- ARTEFACTS, INFRASTRUCTURES AND MEDICAL PRACTICES

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Doctoral Dissertation

To my mother and father

ABSTRACT

Globally, health care is making huge investments in information technology. Several studies illustrate that IT implementations have been fraught with problems. Everywhere, the problems appear to be similar, irrespective of the national health care system. The full potential of these technologies is not achieved, and their use is thus limited. At the same time, it is reported that 60 % of the radiology departments in Sweden are planning to introduce Picture Archiving and Communication Systems (PACS) by the year 2002. The overall research question in this study was; how can we improve the design, implementation and use of PACS by studying the complex interrelationships between the medical staff, the technologies, the work practice and the Healthcare community as a whole? Four ethnographic field studies at different radiology departments in Sweden were conducted. These involved interviews, video documentation and observations of radiological practice and social interaction. As the theoretical framework, various concepts from Actor Network Theory and the concept of Borderline issues were applied to explore the complex interrelationship between medical staff, medical staff and technologies, and various technologies within Healthcare. The study illustrates that when analog films were replaced with PACS images, not only technical devices were integrated, but the people, work practices and organizations as well. It also shows that by studying how the properties of artefacts are used in work practice, we get an idea of the essential resources and prerequisites for the work being done. This knowledge helps us to understand what resources the new information technology should and could replace in a transformation, even if there is no guarantee that it will be used as expected. Furthermore, the study concludes that the larger the socio-technical medical network implementing PACS the harder it will be to coordinate the actions of all actors in a change. Therefore, the study suggests that the infrastructures and work practices can only be changed in a process where smaller parts, are replaced by new ones bit-by-bit. To achieve the "real" opportunities of PACS technology will take time. It is suggested that one way to improve PACS use is to consider it as a "*work oriented infrastructure*" (WOI). This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. These infrastructures should be designed and implemented primarily by their users, based on their actual use of the technology. WOIs are constructed by linking artefacts together. The old and the new socio-technical networks must be linked through interfaces, enabling networks with different technical solutions to communicate and interact. To summarize, firstly, to improve the application of PACS and RIS in medical practice, the design of computer systems has to be informed by a better understanding of all the roles and meanings of the x-ray films and paper request forms in work. Secondly, there is a great potential for improvements in performance of these systems through relatively simple means, by implementing the achieved knowledge in the medical actor network.

Keywords
IS and Healthcare, artefact, infrastructure, interpretive field study, actor-network theory, PACS

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PREFACE

This thesis is a study of IT use in health care. The objective is to gain in-depth insight into radiological practice and its links, in order to inform the design of Picture Archiving and Communication Systems (PACS) and to improve their application within health care. The use of IT is illustrated by empirical studies and theoretical considerations of artefacts and infrastructures in medical practices. IT use is interpreted from the perspective of Actor Network Theory (ANT). This theory assumes that technologies are always defined through their use, in an environment that includes non-technical elements. In the same way, humans are defined through their use of artifacts – our existence in the world is based on the existence of these objects. This means that technologies are not defined by their "internal" material aspects, but rather by their relationships to other things and people in work. The overall research question in this study is*: how can we improve the design, implementation and use of PACS by studying the complex interrelationships between the medical staff, the technologies, the work practice and the Healthcare community as a whole?*

This thesis was conducted at the Department of Informatics, Göteborg University, Sweden, the Department of Informatics, Oslo University, Norway, the Pediatric Radiology Department, The Queen Silvia Children's Hospital, Gothenburg, Sweden, the Thoracic Section at the Radiology Department, Sahlgrenska University Hospital, Gothenburg, Sweden, the Pediatric Radiology Department, Astrid Lindgren's Children Hospital, Stockholm, Sweden and the Radiology Department, Örebro Medical Center Hospital, Sweden. This work was also a part of the Internet Project, which was an international research project of more than 20 researchers from informatics, ethnology and computing. This work was partly funded by the Swedish Transport and Communications Research Board (Kommunikationsforskningsberedningen) through its grant to the Internet Project.

The thesis consists of an introduction and five papers. The introduction describes how the individual papers are interrelated, how the overall question relates to the interpretative research and theoretical approaches applied, and approaches to informing the design of PACS in order to improve their application within health care. The five individual papers are listed below:

The five individual papers are listed below:

1. Lundberg N. (1999). Impacts of PACS Technology on Medical Work. *Proceedings of the International ACM SIGGROUP Conference on Supporting Group Work GROUP99*, edited by S. C. Haynes, pp. 169-178, Phoenix, USA: Arizona State University West, USA.

2. Lundberg, N. and Tellioglu H. (1999). Understanding Complex Coordination Processes in Healthcare. *Scandinavian Journal of Information Systems*, edited by J. Heikkilä, pp. 157-181.

3. Lundberg N. & Sandahl T. (2000). What do Artefact Mean to us in Work? *Proceedings of the 22th IRIS*, edited by T. K. Käkölä, pp. 363-372, Jyväskylä, Finland: University of Jyväskylä, Finland[1].

4. Hanseth O. & Lundberg N. (2000). Designing Work Oriented Infrastructures. Accepted in *Computer Supported Cooperative Work (CSCW): The Journal of Collaborative Computing*.

5. Lundberg N. & Hanseth O. (Submitted as a book chapter for publication). Standardization in Practice – Examples from Healthcare. "*Strategies of healthcare information systems*", editor Ton AM Spil and Robert A Stegwe, in relation to HICCS-34, Maui, Hawaii, January 3-6 2001[2].

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1 Submitted to the 34th Annual Hawaii International Conference on System Sciences (HICSS-34), Maui, Hawaii, January 3-6 2001.

2 A previous version of paper 5 is published in Proceedings of the Fourth International Workshop on CSCW in Design (CSCWD 1999), edited by J. P. Barthes, L. Zongkai, M. Ramos, pp. 407-414, Compiègne, France: University of Technology Compiègne, France.

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CONTENTS

IT in Healthcare

- Artefacts, Infrastructures and Medical Practices

Nina Lundberg

IT Implementations in Healthcare

Globally, health care is making huge investments in information technology. Health care expenses represent some 7-12 % of the GDP in the industrialized countries. Large, complex and expensive information technologies dominate these investments. The introduction of these technologies emphasizes the replacement of the old analog “infrastructure” (Bowker and Star 1995, Hanseth 1996) technologies, such as X-ray films and paper documents, with the new electronic ones. Several studies have identified problems related to the implementation of these complex technologies, e.g. Picture Archiving and Communication Systems (PACS) and electronic medical records (Collin 1995, Heath and Luff 1996, Strickland 1997, Nagy et al. 1997, Bryan et al. 1998, Berg 1998, Wild et al. 1998). There are a few dominant vendors. Each vendor has its own system, which does not vary by country - one buys the same system in USA, China and Sweden. The full potential of these technologies is not achieved, which restricts their usefulness. Therefore, there is a need to study more closely how the design, implementation and use of IT (information technology) in health care can be improved. To improve the potential of IT in healthcare, we need to understand the underlying reasons for the failure to realize its full potential. We gain some insight into this question by focusing on the close interrelations between the medical staff and the technologies, the work practices and the health care community as a whole.

Medical work is a highly complex, distributed, dynamic, regulated, knowledge-intensive and often time-critical activity. To make treatment of ill and/or injured patients possible in these time-critical, specialized and physically distributed work settings, medical staff constantly need to cooperate with each other. Cooperation in these distributed medical work settings requires extensive coordination between the medical actors involved. To facilitate this coordination medical work is heavily regulated by procedures and conventions, as well as supported by a number of technologies like paper documents and analog films that are used by a large number of medical actors for many different purposes. These technologies are not isolated artefacts but social and material parts of work. Therefore the design of IT is addressed in this study as the design of work practice. And artefacts in this work is addressed as “artefacts in use” as described by Cole’s “An artefact is an aspect of the material world that has been modified over the history of its incorporation into goal-directed human action. Bye virtue of the changes developed in the process of their creation and use, artefacts are simultaneously *ideal* (conceptual) and *material*. They are ideal in that their material form has been shaped by their participation in the interactions of which they were previously a part and which they mediate in the present (Cole 1996, pp. 117).

This thesis is structured as follows: after describing the aim and setting of the study, an overview of IT in Healthcare from research within the medical informatics, Computer Supported Cooperative Work (CSCW) and Information Systems (IS) fields is provided in sections 4 and 5. Sections 6 and 7 outline the joint theoretical and empirical background of this study and present the research approach described. Section 8 gives the main results from the papers. Finally, there are sections on informing design, concluding remarks and future research (9, 10 and 11).

Aim of the Study

The main research question in this study is: How can we improve the design, implementation and use of PACS by studying the complex interrelationships between the medical staff, the technologies, the work practice and the Healthcare community as a whole? The aim of this research is to inform the design of Picture Archiving and Communication Systems (PACS) by understanding the radiological work practice and its links in detail.

This thesis work emphasis interrelationships between various entities because the different elements are linked together in the sense that each of them is based upon the existence of the others, and the role of each is defined in terms of how this role fits together with and links with the other elements' roles.

The main overall research question is addressed by considering the following issues:

1. How does the transformation from analog films to digital images change medical work practices and interdependencies in work?

2. How are human actors, technologies and human actors, and various technologies linked together within the radiological practice?

3. How do the specification and prototype-driven standardization approaches respectively influence and form the information technology in use?

4. What factors should be considered in the design and application of PACS within Healthcare?

Research Context

In this section a brief description of the radiological context surrounding the empirical research i.e., the radiology departments in Sweden, and in particular the diagnostic service offered by them is provided.

The radiology departments

The empirical research presented in this thesis was mainly carried out at three radiology departments in Sweden. A first study was carried out at the Pediatric Radiology Department, The Queen Silvia Children's Hospital, Gothenburg, Sweden. This is a department working in a "film environment", where films are produced, archived and distributed manually. A Radiological Information System (RIS) – is used at an administrative level, supporting patient administration, producing economic and statistical information for the hospital management board. It specifies patient demographics and the types of examinations carried out at the department.

A second study was carried out at the Thoracic Section at the Radiology Department, Sahlgrenska University Hospital, Gothenburg, Sweden. When you enter this section you enter a "film-less" (PACS-based) environment where images are generated, stored and transferred electronically. This PACS technology has been developed in-house, and it is integrated with a vendor-supplied RIS through a shared interface. In this department, the RIS helps manage ordering and scheduling as well as the radiological patient records. It is thus used for both clinical and administrative work.

A third study was carried out at the Pediatric Radiology Department, Astrid Lindgren's Children Hospital, Karolinska University Hospital, Stockholm, Sweden. This is also a "film-less" department based on a vendor-supplied PACS technology that has no integration with the RIS, although the functionality of the RIS technology is similar to the Thoracic Section's, at the Radiology Department, Sahlgrenska University Hospital.

In addition, a comparative study at the Radiology Department, Örebro Medical Center Hospital, Örebro, Sweden has been conducted. This is also a "film-less" department, based on a vendor-supplied PACS and RIS that have been tightly integrated by the vendors in a shared interface. Finally, this research work has been compared with other studies of PACS in Austria and Denmark (Paper 2).

The choice of the sites for my empirical work was based on the fact that they were among the few Swedish institutions that were using PACS in work practice at the time, with the exception of the Pediatric Radiology Department, The Queen Silvia Children's Hospital. This was chosen as a suitable example of a traditional radiology department, including all types of radiological examinations.

The radiology departments employ staff in varying occupations. Radiologists carry out patient diagnosis and intervention. Radiographers work with image production and quality control. Typists transcribe the radiologists' reports. Computer technicians support all the other actors with regard to computer systems. Administrative staff serve as the link between the radiology department and the outside world, and file-room staff organize, store and distribute X-ray films. In this thesis a medical staff is often referred to as "communities of practice" as defined by Lave and Wenger (1991): a community of practice is a unit of analysis that cuts across formal organizations, institutions like family and church, and other forms of association such as social movements. It is simply, a set of relations between people doing things together. The activities, with their routines and exceptions, are what constitute the community structure. Newcomers to the community learn by becoming 'sort of' members. The following section describes the radiological service offered by the radiological staff.

The radiological services

Radiology departments are service units for clinical departments inside the hospital, other hospitals, primary care units and general practitioners. The services delivered mainly comprise diagnostic reports, but some therapeutic interventions and procedures, e.g. dilatation of vascular obstructions, are also performed. The diagnostic reports are based on X-ray and other types of radiological images. The different types of radiological examinations offered by large and medium-sized radiology departments in Sweden are: skeletal, chest, mammography, ultrasound, odontological, gastrointestinal, urinary tract, vascular examinations, computer tomography (CT) and magnetic resonance (MR). Some of these examinations are not only performed at the radiology department but also in the wards, in the intensive care units, etc. Examinations such as MR and vascular interventions are usually not offered at smaller community hospitals.

The radiological services may be requested by doctors of all other specialties within a hospital. At Sahlgrenska University Hospital, which is one of the sites of my empirical research, there are some 60 specialties with about 7000 staff members (of whom approximately 80% are women), 1100 inpatients and numerous outpatients mostly from the hospital clinics, primary care units, general practitioners and the emergency department.

To make the diagnostic work more effective and to improve the services delivered, many radiology departments are planning to invest or are in the process of investing in Healthcare management systems, such as PACS and RIS. Briefly, PACS digitize and automate image acquisition, communication, exchange and storage, while RIS digitize ordering, scheduling and the radiological patient record. The PACS and RIS products and services currently available to diagnostic imaging organizations are costly, and most PACS and RIS require an investment of $7-12 million in order to acquire the software and hardware necessary to implement a system. The trend has been that a few manufactures dominate the PACS market and often do not integrate their systems with the variety of RIS or with practice management tools available to diagnostic image centers.

The radiological work

Medical work is a highly complex, distributed, knowledge-intensive and often time-critical activity. In Healthcare, the treatment of one patient often involves a number of distributed interconnected departments and activities. Specialized staff need to work together in the treatment of patients; they constantly need to coordinate their work with each other – to ensure the best treatment possible for the patient. To facilitate this cooperation and coordination the work is heavily regulated by procedures and conventions, and it is supported by a number of technologies. An example of such a technology within radiological work is PACS. The activities supported by PACS involve image creation, retrieval, display, manipulation, storage and distribution. PACS support radiologists' diagnoses, which provide the information for decisions on patient treatment, i.e. on the basis of this information the clinician will decide on procedures for patient intervention, medication, etc. The diagnosis delivered by the radiology department gives clinical staff the opportunity to deal with illnesses when they occur.

Radiological work involves making diagnostic decisions. To obtain the diagnosis, work is divided between different spaces and actors with an emphasis on achieving a "streamlined workflow". The conduct of work can be achieved only through skilful and extensive use of conventions, procedures and technologies, without which a great deal of negotiation and conversation on coordination issues would constantly be necessary (Paper 2).

The diagnostic work progresses from one activity to another, just as the responsibility for the patient moves from administrative staff to radiographers to radiologists, etc. This means that the work done by one actor is of interest to the next actor, and is documented in the paper request. This written information supports medical actors in planning their own work just as it enables them to hand over medical work to other medical actors.

There is an extensive need for coordination in radiological work – for continuously keeping medical actors up to date, enabling them to take action and make appropriate decisions. In radiology departments, the most important technologies currently used for conveying or coordinating patient diagnoses are paper documents and films. Despite paper's apparently simple structure, the skilful and shared use of this technology is fairly complex (Paper 3). The same is true of the film technology – it also seems to be a simple technology, but is in practice surrounded by a hidden and complex film diagnostic process. The following section briefly describes the PACS in use (for more detailed descriptions of the film diagnostic process and the PACS diagnostic processes, see Paper 1, 2, 4 and 5).

PACS in Use

PACS – Picture Archiving and Communication Systems – are the globally used applications for electronic storage, retrieval, distribution, communication, display, and processing of medical image data. PACS date back to the early 1980s, when Healthcare focused on information technology's ability to communicate, exchange and distribute image information in an accessible and fast format. Most PACS products are based on the technical standard "Digital Imaging and Communication in Medicine" (DICOM). Beginning in 1995 some 8% of the radiology departments in Sweden have now (1999) implemented PACS. The initial aim of using PACS was to replace films or the entire film diagnostic process with electronic images based on PACS to improve the creation, distribution, communication and exchange of medical images between physically distributed actors, and hence to make the Healthcare practice more effective and efficient. A number of references provide a historical presentation of PACS and the DICOM that standard PACS products are based on (for example, Hindel 1994, Jost 1994, Parisot 1994, Donizelli and Giachetti 1998).

The central role of PACS is to store and distribute images. However, PACS are also designed to support other functionalities in radiological work. For example, 1) in image production users can manipulate images' gray scale, size, and orientation (rotate or invert the images), 2) in image saving and archiving users can create "electronic lists" (desktop folders) that support the organization and management of work, 3) in image distribution PACS support the communication with other nodes in the network, 4) in image prefetching, display of old images, image analyses and diagnosis, radiologists can measure angles and areas on the image and display images in stacks by scrolling between them, and finally 5) in clinical image demonstration, PACS are used to fetch and display images[3].

PACS are closely linked to RIS in most activities in radiological work, for example 1) in the administrative activity, when the patient is scheduled in the RIS, a message is automatically transferred from the RIS to the PACS. This message triggers the automatic retrieval in advance of relevant examinations from the long-term PACS archive. 2) In the image production, quality and evaluation activity, the radiographer uses a hand scanner to scan the barcoded ID sticker attached to the paper request. This triggers retrieval of the patient's digital data and images on the workstation, from RIS as well as PACS. 3) In the diagnostic activity the radiologist retrieves patient data and images on the workstation in the same manner as the radiographer did. Three monitors are situated side by side, in front of the radiologist. On the left-hand one, the PACS and RIS are integrated into one interface, while the middle screen displays the new images and the right-hand screen displays the old images. When the radiologist browses through various new images, the corresponding old image

3 For a more technical description of PACS functionalities, see Greinacher (1994).

will automatically be displayed on the right-hand screen. 4) Both PACS and RIS are also essential during the ad hoc discussions between radiologists and clinicians as well as during the daily interdisciplinary meetings. During these sessions, medical staff use PACS and RIS as they do in the diagnostic activity. Therefore, in order to understand the use of PACS, we also need to understand the role and use of RIS.

A hospital can introduce PACS at different levels of use. The radiology department introducing a "*first-level PACS*" (Tellioglu and Wagner 1996) works with many "unconnected" modules for local production of digital images in the different laboratories. This means that the radiographer views and selects electronic images, adjusts the density level to produce the optimum image, and performs any reorientation and annotation. She thereafter prints the electronic images as analog films (on laser printers). Radiologists then diagnose the analog films. At what we could call the "*second level"*, PACS use include a local network connecting the different image production modules, the archive, the hardcopy machine, and the diagnosis and reporting workstations. In this environment the radiographer carries out image production and quality control of images in the same way as in the first-level PACS. Images are electronically distributed and radiologists retrieve patient data on workstations. The radiologist zooms and uses the tools to magnify and change the contrast of images. Manipulation of the images on the workstations allows a range of densities to be seen in the image, just as it allows the instant measurement of various findings. Images are compared, for example by switching between images showing different views of the patient's chest. All images are stored in the PACS archive. If clinicians request images, these are printed either as analog films or as an image on paper and manually transported to the requesting clinical unit. A "*third-level"* large-scale PACS functions in a hospital-wide electronic network, not only connecting the entities listed in second-level PACS, but also connecting to workstations in clinical units within the hospital. This means that clinicians in practice receive and retrieve electronic images via workstations linked to the PACS archive.

To the best of my knowledge there are no PACS and RIS systems integrated with any Hospital Information Systems (HIS) at a hospital in Sweden so far. This means that the radiology departments always receive "paper" examination requests, and always need to deliver the diagnostic answer manually as a paper document. In order to access the information electronically within the radiology department, many departments scan the received paper request.

Related Research

Having described the technologies that form the major focus of this thesis, I wish to turn to the related research, which represented the background literature for these studies. Related research in Healthcare has been conducted in several fields: medical informatics, medical sociology, CSCW (Computer Supported Cooperative Work) and IS (Information Systems).

Medical informatics has emerged as a technically oriented field (for example, see Lorang et al. 1998, Todd-Pokropek 1998). In the field of medical sociology, thorough and detailed research on social relationships and complexities of medical work has been conducted (for example, see Strauss et al. 1985, Berg 1998). CSCW has developed as a research field within IS, also including various perspectives on cooperation and coordination of work within Healthcare (for example, see Heath and Luff 1992, Hughes and King 1993, Schneider and Wagner 1993, Kjaer and Madsen 1995a, Symone et al. 1996, Tellioglu and Wagner 1996, Bardram 1997). The following subsections describe these fields' different interests and findings in more detail.

The medical informatics field

The studies conducted within the medical informatics field emphasize technical descriptions of new technologies. To illustrate this, I have categorized the articles from EuroPACS98 (Piqueras and Carreno 1998). Out of the 46 articles, 28 addressed technical descriptions of clinical applications: PACS, Web technologies, teleradiology solutions, 3D and multimedia applications; 10 addressed image acquisition; seven addressed HIS-RIS-PACS integration; five addressed PACS management and health economics; and two addressed the role of PACS in medical practice. The majority were written by medical personnel in charge of or strongly involved in the design, implementation and use of an isolated technology at an individual department. There is a lack of literature addressing lessons learned from implementation problems, as well as technology seen in the context of its use in medical work practices. The "absence of benefits" from PACS use is rarely addressed. I agree with the general argumentation of this field that it is important to have a properly functioning technology. However, there are contextual aspects of the work practice that the technology will form part of that are important as well. The implementation of PACS into the radiological practice is a process of repeated negotiations. In the trajectory of negotiations that follow, the social and material aspects of work, including the technology itself, may all be transformed.

The process of implementing and using PACS have been remarkably slow. Lundberg (1993) reported from an enquiry distributed to 30, 28 replies, radiology departments in Sweden that 69 % of these hospitals had implemented a digital network, but none of the radiology departments made use of it, although the majority planned to do this in the near future. Laurin reported (1998) that only five of all 132 radiology departments in Sweden had implemented PACS. Brian et al. (1998) reported the delay of the Hammersmith Hospital's PACS implementation and blamed it on the insufficient maturity of the technology. It could also be due to the overly optimistic expectations for the technology. Another reason to delayed PACS projects might be that designers do not pay sufficient attention to the medical context (Paper 3, Paper 4). A further explanation might be that there has been too little emphasis on the socially organized practices that need to be developed and shared around the technology and its use, in order to realize the opportunities it offers. Of course, the financial problems within Healthcare, for instance in Sweden, have also been a delaying factor. Thus, the difficulties related to the process of implementing and using the technology are related to many other factors than to the technology itself. Delays in IT projects are not an isolated phenomenon for Healthcare; this is a problem in IT implementations in general.

Many authors have stressed the importance of diagnostic accuracy of digital technology (Martonossy et. al 1998, Todd-Pokropek 1998, Tzalonikou et. al 1998, Weatherburn and Davies 1998), because, the digital image accuracy has been a necessary prerequisite for the process of implementing and using PACS. The medical informatics literature suggests that the accuracy of conventional film is equal to or greater than that of digital images viewed in workstations or printed on films (Strickland 1997, Bryan et al. 1998). Users found that the increasing contrast resolution provided by softcopy manipulation of the image more than compensated for any reduction in digital image resolution. Data suggests that the diagnostic accuracy of digital images is improving (ibid.). The radiologists considered the quality of digital images to be “sufficient” for radiological diagnostic work (Strickland 1997). According to Almazán (1998) the patient samples presented in the comparative studies are usually quite small, e.g. 30-40 patients, and it might therefore be difficult to detect significant differences in the evaluation of diagnostic accuracy.

A strong argument for introducing PACS has been its potential to increase the organization’s efficiency. However, research literature indicates that there is limited evidence to prove increased efficiency in the Healthcare process (Bryan et al. 1998). Almazán (1998) makes the point that it might be that the changes in efficiency are invisible to the methodologies researchers use to measure them.

The studies conducted have shown that PACS generate and provide images more efficiently than conventional radiological work (Strickland 1997, Almazan 1998, Bryan et al. 1998). Another benefit is that fewer images are lost than in diagnostic processes using films. These studies have also highlighted the fact that multiple users may access one electronic X-ray image simultaneously. One might conclude that generating, receiving and accessing the images more quickly would improve efficiency in the Healthcare chain, resulting in faster intervention for the patient. However, studies focusing on efficiency (Strickland 1997, Almazán 1998, Bryan et al. 1998) only found a small and insignificant overall improvement. According to Almazán (1998) this may be due to the need for other examinations, such as lab tests, to support a decision on therapeutic strategy. Another reason suggested in the literature is the lack of integration between PACS, RIS and HIS (ibid.). There are numerous reasons why this integration is so vital. For example, it can improve information flows within Healthcare, just as it can keep administrative work at an acceptable level. Administrative work such as repeated entry of the same data on different computer systems could be avoided.

Initially, the hypothesis that the time devoted to interpreting images on a workstation might be higher than with the conventional system has been postulated (Strickland 1998). However, studies conducted that have measured these events show that the same time was needed (ibid.). This is, of course, related to the experience of the radiologist. An inadequate use of PACS might both result in reduced diagnostic accuracy and more time needed to interpret images. Regarding organizational changes related to the implementation and use of PACS, no study has been found that assesses this subject (Almazán 1998).
These studies illustrate that there has been a great deal of talk about PACS for the last twenty years, but few implementations. They also illustrate that PACS implementations have been problematic, and PACS have not yet generated the "great efficiency" improvements that medical staff expected at first. Major work within this field has focused on technical issues. Of course, a technical perspective - for instance on the accuracy of digital technologies - is also necessary for radiological diagnostic work. In order to understand why these efficiency improvements have not yet materialized, we need to look deeper into PACS and the medical work practice related to it. Such descriptions can be found within the social science field and the technology studies field. The following section discusses the findings from the social science field in more detail.

Medical Sociology

Medical work is complex, partly because of the continuous unexpected contingencies that arise. According to Berg, "…medical personnel are engaged in a never-ending process of ad hoc rearticulations" (Berg 1998, pp. 134). This may be due to the delivery of an unexpected X-ray diagnosis or a new supervisor who disagrees with the policies of the previous one, etc. Medical staff are continuously working, managing with odds and ends, to perform their tasks in keeping the patient's trajectory on track - while, concurrently, reconstructing its course (ibid.). Strauss et al. have also shown that "…there is a high likelihood that schedules will go awry, emphasizing that each patient care unit has its own schedules and contingencies. For example, in a radiology unit there may be a machine breakdown for which staff are unable to arrange immediate repairs, or a key staff member may be tied up elsewhere, or a higher priority "emergency" may suddenly develop " (Strauss 1985, pp. 5). In the illness of a patient usually multiple services are scheduled and there is a high probability that his or her total schedule will go awry (ibid.).

It is important to point out that the patients' unfolding trajectories can often not be foreseen. An apparently simple illness may prove unpredictable. The patient may develop post-surgical infection or other complications, or prove to be allergic to a drug. Some such contingencies are easy to deal with. Others, coming in the wake of more uncertain courses of illness, are more difficult to handle. When the medical trajectory becomes problematic, then the classic conception of medical work may be far from accurate (Strauss et al. 1985).

A well-researched investigation of technologies in medical practice was conducted by Strauss et al. (1985). According to the authors, a walk around the hospital will quickly reveal which sections of the building rely most on machinery. As Strauss et al. (1985) points out diagnostic sections are full of equipment and people working with it, just as radiological departments include various X-ray machines and computerized image production technologies. The machines themselves are immensely varied. They include machines utilized for diagnosis, therapy, and monitoring, for relieving discomfort, or as a substitute for an impaired bodily part or system, and frequently they have a life-sustaining function (ibid.). There are also communication technologies used for locating key personnel when they are urgently needed, e.g. paging systems. While some medical specialties use little or no machinery, others could scarcely continue without equipment. For example, the treatment of cancer involves radiation, X-ray diagnosis, and laboratory examinations. Strauss et al. show that a special feature of medical specialization and technology innovations is that the two are simultaneously parallel and interactive, "…medical specialization leads to technological innovation: the technological innovation then leads back to medical specialization" (Strauss et al. 1985, pp. 4). The tool and the practice are transformed into each others' image: the practice is redesigned to mirror the tool's formal structure, and the specific contexts from which the tool emerges are inscribed in its design. Through the mutual transformations, the medical knowledge embedded in the tool is inextricably interwoven with its "context" (Akrich 1992).

In summary: findings from the medical sociology field have been of great importance for me in my own introduction to and understanding of medical work. These studies illustrate that medical work is rarely predictable, even in the simplest illness. In complex, distributed and often time-critical activities, medical staff is heavily dependent on various technologies. One way to improve Healthcare is therefore to improve the technologies supporting it. In order to improve these technologies we need to look deeper into how the different technologies enable and restrict work practices in various ways in different situations. Such descriptions can be found in the CSCW and IS fields. The following section addresses the findings from these fields related to Healthcare in more detail.

The CSCW and IS Fields

The CSCW and the IS fields have also been concerned with IT in Healthcare. CSCW has emerged as an interdisciplinary research field that focuses on the design of computer systems to support cooperative activities within groups, e.g. enabling them to work together in new ways. One of CSCW's distinctive design features is its focus on understanding and investigating the character of social cooperative work on the background of IT use. To some extent, the data from these studies tend to be based on or inspired by findings from several disciplines (for instance, social science - see the previous section). The following subsections describe some of these studies in more detail.

Various studies of information technologies in radiology departments have been conducted from different perspectives. Wagner (1994) and Tellioglu and Wagner (1996) have looked at the use of information technology from a “political perspective”. This means that they have emphasized the importance of organizational negotiations in medical work, between different communities of practices. In the initial study Wagner (1994) suggests that technologies may not only introduce new logics and rationalities; they may also create new terrains across professional and departmental boundaries. For instance, transforming the paper document into an electronic document may also be related to the reinforcement of hierarchies. The fact that forms requiring signatures can be modified only in consultation with the doctor in charge of the patient is an example of materialization that embeds and sustains hierarchical relations (ibid.). When the PACS system was introduced at radiology departments, it did not intensify interdisciplinary dialogue (Tellioglu and Wagner 1996). Instead, electronic space replicated traditional boundaries and hierarchies of knowledge (ibid.). Tellioglu and Wagner (1996) suggest that the reinforcements of hierarchies are political negotiations and organizational decisions rather than changes triggered by the technology itself. What can be learnt from these studies is that the technology has the potential to support new logics and rationalities, but that the technology in itself cannot cause these changes. It is suggested in this thesis that the realization of such changes lies in the process of making the technology embedded in work as well. This implies that the same technology implemented in different places may generate many different effects.

Interest in what is needed to realize intended changes within Healthcare has inspired several research studies. For instance, Kjaer and Madsen studied the role of computer applications in a changing radiological setting (1995a, 1995b). They proposed a conceptual framework that focused on four different aspects of organizations – work activities, technical artefacts, space, and work organization. They investigated the dependencies between elements that represent the relatively stable and dynamic aspects of the organization and studied how the flexibility of one element can either trigger or constitute a barrier to change in another element (1995a).

Authors such as Heath and Luff (1992), Luff et al. (1992), as well as Harper and Sellen (1995) have emphasized the importance of the medical document’s properties. They suggest that the fact that written documents (not emphasizing a large pile of documents) are tangible, ecologically flexible[4] and “light” has implications for the ease with which they can be physically transported within the communities and laid out in particular spaces. According to Hughes and King (1993), understanding the use of medical records means understanding the kind of work activities in which they are embedded. These authors also conclude from their study that the movement of a document or a record between

[4] Refers to the fact that documents can be brought to many different contexts in which they fulfill. some aim and purpose.

organizational settings is not merely the movement of a piece of paper, but is a process of transformation of organizational work (ibid). For instance, people tailor their documents to differentiate and highlight particular items. These topics are also covered by Luff et al. who stress that "…doctors may underline or mark text with colored pens in records to alert colleagues to irregularities in treatments, and architects sketch in and ring changes to their plans" (Luff et al. 1992, pp. 164). It is relatively easy to add information to paper documents that is essential for their application in work situations. Luff et al. (1992) propose that paper documents have a capability to be adapted to a range of situations and contingencies (ibid.). For instance, a doctor can examine a patient with an eye on the record at the same time, just as doctors can compare records to evaluate different treatments when they brief other doctors (ibid).

The process of moving and using paper records between organizational activities and institutions is supported by several conventions in work. Berg (1998) refers to these shared conventions and procedures of action as "protocols". He stresses that the importance of the protocols is that they stretch out across a larger community. A protocol lays out a path of work (Berg 1998); "…it accumulates, coordinates and mediates work practice" (Berg 1999, pp. 387). Through standardized protocols, medical practices improve the production of data needed for patient treatment, by aligning individual efforts and increasing communication. However, Bowker and Star (1999) have argued that standardization procedures must be tailored to the degree of granularity that can be realistically achieved.

So far, this change from paper to electronic documents in hospitals applies mainly to drug prescriptions and the exchange of test results (Monteiro and Hanseth 1995). Monteiro and Hanseth (1995) note that in the process of designing electronic documents it is important to focus on how the technical standards that the electronic documents are based on, can be embedded in work. To design information technology, these authors suggest, it is not enough to know there is an interaction between human and technologies in work. We need to be more specific about the technology in use; we need to incorporate a more thorough description and understanding of the technical properties, and how these are transformed into non-technical ones in work practice (Monteiro and Hanseth 1995). An example might be the properties of paper documents, as described by Luff et al. (1992), applied in work. There are many aspects involved in the design and establishment of standards. A number of studies suggest that standards are in fact anything but neutral (Bowker and Star 1999, Star and Ruhleder 1994, Monteiro and Hanseth 1995). They may either trigger or constitute a barrier to change in work. According to Bowker and Star (1999), the development of standards is the result of political and social work.

From descriptions of the diverse and complex use of paper documents in medical practices (Luff et al. 1992, Hughes and King 1993, Harper and Sellen 1995, Heath and Luff 1996, Sellen and Harper 1997), it is clear that the transformation from paper medical documents to electronic documents is a challenge.

The studies in this section emphasize technology's role in organizational change within Healthcare. It is argued that information technology has the potential to support new ways of working and new services, but cannot itself create such changes. The reason for this is that organizational change is not just a matter of technology. The diverse and complex use of paper documents is also illustrated. Furthermore, it is illustrated that the use of one and the same technology may become manifold and different between various groups, since the different groups may develop different procedures and conventions around the use of a technology. This implies that we need to look closely and thoroughly at the technology in use in order to understand its meaning in work.

Summary of PACS studies within Healthcare

The studies from the *medical informatics* field illustrate that the early technical problems related to PACS have been solved. This is important, since the accuracy of PACS is a prerequisite for the implementation and use of PACS. However, in spite of the solutions that have been found for the technical problems, studies from the medical informatics field also illustrate that PACS implementations have been problematic. So far the great efficiency improvements that medical staff initially expected have not yet been achieved (Strickland 1997, Bryan et al. 1998). Therefore, it seems reasonable and important to explore the reasons for the problems experienced with PACS implementation and use. A prerequisite for insight into these problems is a thorough understanding of the traditional radiological work practice. This understanding contributes knowledge about what is to replace technologies, coordination, communication, people and work practices in the transformation from films and paper documents to digital images and documents. In medical informatics, there is a lack of studies regarding traditional radiological practice.

Medical sociology has made detailed studies of medical work. These studies are relevant to the design, implementation and use of PACS, since they contribute an important understanding and description of the "medical milieu" in which PACS will be established. In addition, studies within this field have shown the interrelation between technology and medical work, e.g. how medical specialization leads to technological innovation, and how the technological innovation in turn leads to medical specialization (Strauss et al. 1985). However, they have not studied PACS' impact on radiological work and vice versa. Therefore, it seems essential to analyze and identify how PACS technology shapes and is shaped by radiological work - especially since 60% of all radiology departments in Sweden are in the process of introducing PACS or planning to introduce PACS by year 2002. This knowledge may support the medical staff involved in this transformation process. A prerequisite for understanding the impacts of PACS on radiological work is a comparative study of the traditional and PACS-based radiological practice. Such a comparative study contributes knowledge of overall efficiency improvements, as well as how activities and interrelations between medical staff are changed. Comparative studies within the medical sociology analyzing and identifying PACS impacts on the radiological practice are needed.

An important contribution from the *CSCW field* is Wagner's (1994) suggestion that information technology has the potential not only to introduce new logics and rationalities, but also to create new interrelations between professionals and departments. Wagner's (1994) study is essential, since it contributes important knowledge of the changed conditions relating to work with information technologies within Healthcare. However, in a later study, she and Tellioglu (1996) found that the new and changed conditions were not explored and applied in relation to work with PACS. Instead, the traditional interrelations, e.g. boundaries and hierarchies of knowledge, were replicated (Tellioglu and Wagner 1996). This suggests a need to explore why the traditional ways of working were replicated when the conditions for carrying out work with PACS were changed. A prerequisite for this understanding is a thorough and detailed understanding of particular links in medical practice, e.g. how medical staff, technologies and medical staff, and various technologies are linked together. Knowledge of the number, extension, and durability of links in medical work may help to explain why the traditional way of working is replicated in work with new technologies such as PACS. Studies within the CSCW and IS fields that focus on the links in medical practice, and radiological practice in particular, are needed. Furthermore, follow-up of Wagner's studies (1994, 1996) seems warranted, to explore how the potential interrelations (Tellioglu and Wagner 1996; Bryan et al. 1998; Strickland 1998; Paper 1) can be developed in radiological practice. A prerequisite for understanding how to develop new interrelations in work is a thorough understanding of particular links in medical work, e.g. how medical staff, PACS and medical staff, and various technologies are linked together. This is especially relevant since this understanding contributes knowledge about which information in PACS may be useful in the development of new interrelations in medical work. Studies within the CSCW and IS fields on the links in medical work supported by PACS are needed.

Other studies from the *CSCW and IS fields* that have an obvious relevance for the transformation from analog to digital technologies within Healthcare are the studies contributing important knowledge of paper documents and their application in work (Luff et al. 1992, Hughes and King 1993, Harper and Sellen 1995). These studies inform designers of particular prerequisites for a transformation from paper requests to electronic requests. However, if a radiology department is to meet the objective of becoming paperless, a more complete understanding of the paper requests roles in radiological work is needed. To achieve a paperless department, one must provide the electronic document with the essential meanings and roles of the paper request. Studies within the CSCW and IS fields that focus on the essential meanings and roles of paper requests and their establishment in radiological work are required.

Theoretical Background

Views of the role of IT in organizational change have varied immensely over the years. Accordingly, IT literature from various perspectives has emerged. In reviewing these views, I briefly outline the technical determinism and social constructivist positions. Thereafter, Actor Network Theory (ANT), which is increasingly applied in the IS field as an intermediate perspective, is outlined. ANT, in particular, is reviewed to provide a theoretical background for the individual papers of the thesis, before listing other intermediate positions as found in the IS field. I then supplement the various perspectives on the role of IT in organizational change by outlining the different views on IT and its use over time. These views range from regarding computer technology as a tool that supports information processing to seeing it as a network that supports interactive communication "globally".

Technological determinism described technologies as something that, when in use, forces the human actors to behave in a specific way (see, for example, Winner 1977). According to this perspective the effects of technology can be predicted, since the technology is the only factor that has a major impact on behavior. Thus, some authors assume that IT is an exogenous force that determines the behavior of organizational actors - the technology determines its own use. This means that if I as a designer could just find the technology and give it certain "correct" functionalities, I could control the outcome of its use and achieve desired organizational changes. In this way the approach largely ignores the actions of users in developing, appropriating and changing technologies (Jones 1998). As a result, this perspective furnishes an incomplete account of the interaction of humans and technologies, e.g. the social action's influence and contribution to organizational change. A deterministic view of PACS would assume that if the technology is given the right functionalities, its inner logic will imply that cooperative work will take place in ways that generate the great efficiency improvements that have been anticipated in the radiology department and between the radiology departments and its customers. This view has been present among PACS proponents, as they, from the start, have argued for the benefits PACS would generate within medical work.

According to the social constructivist perspective, humans design the technology's use and accordingly can control the impacts of IT themselves i.e. the technology in itself has no properties that effect and impact the interaction with that technology (Bijker et. al 1987). An example of this approach is the social construction of technology (SCOT) program (Pinch and Bijker 1987). This approach examines how shared interpretations of a certain technology arise and determine the development of and interaction with that technology.

Social constructivism was developed as a response to the technological deterministic perspective of technology's role in organizational and societal change. The social constructivist perspective explains IT as something of little importance for organizational change, stating that it is the user in the wider cultural and social structural patterns of specific societies who determine how the technology will be used, and for what purpose (Woolgar 1988, Kling and Iacona 1984, Zuboff 1987). Researchers have criticized the social determinism of this perspective (for example, see Winner 1993). This perspective furnishes an incomplete account of the interaction of humans and technologies, disregarding technology's contribution to organizational change. Several researchers suggest that technological determinism and social constructivism are both insufficient. They emphasize that IT is shaped by humans, although the humans are not in complete control. These researchers have an intermediate perspective on the role of IT in organizational change. I have used Actor Network Theory, as this perspective supports the investigation and documentation of large and heterogeneous socio-technical work practices with numerous actors, such as those found in Healthcare. A more detailed description of ANT and my reasons for using it will be presented in the next two subsections.

Actor-Network Theory

Actor Network Theory (ANT) (Callon 1986, Law 1986, Latour 1987) - an intermediate perspective - emerged in the late 1980s. In an intermediate perspective, changes emerge from the interaction of people, events and technology. Actor Network Theory suggests that both the previous approaches are incomplete: one states that the technology and its impacts are given, while the other states that there are no technology effects – effects are socially constructed. The intermediate perspective stresses the fact that information systems comprise both technical and social elements. It proposes a reconceptualization of technology that allows a deeper understanding of the interaction between technology and organizations. The ANT perspective is a way to move beyond the position in which IT facilitates certain resources and constraints of organizational action (Monteiro and Hanseth 1995). Through its conceptual framework of the actor-network, inscriptions and translations, ANT offers a promising way to provide a more concrete analysis of the relatedness of people and things in organizational change. The concepts will be further described in this section.

In Actor Network Theory, it is assumed that technologies are always defined through their use, in an environment including non-technical elements. As Latour puts it, "…entities take their form and acquire their attributes as a result of their relations with other entities" (Latour 1999, pp. 3). In the same way, humans are defined through their use of artefacts (Law 1992) – our existence in the world is based upon the existence of these objects. Hanseth and Braa discuss the intertwined relation of objects and other entities: "accordingly, neither human nor technological artefacts should be considered as pure, isolated elements, but rather as linked *heterogeneous networks*. When any actor (human or non-human) acts, this very actor is always such a network, not a single element" (Hanseth and Braa 1999, pp. 189). This means that elements in a network are not defined by their "internal" aspects, but rather by their relationships to other elements in the network.

ANT is one way to illustrate work that in reality is large, complex, rich and messy, as in Healthcare. ANT tells "…how to go about systematically recording the world-building abilities of the sites to be documented and registered" (Latour 1999, pp. 21). It is a way to learn from the medical staff: "…what they do and why they do it" (Latour 1999, pp. 19). The theory regards work practice as a heterogeneous actor network. It simplifies work practice and represents it in a way that highlights how human actors and artefacts (non-human) are intertwined in order to reach a goal. ANT thus emphasizes that establishing and changing a work practice relies on a close interplay between social and technical means. In this thesis work actor network theory is used to explain the path of technical implementation in which humans and technology coevolve.

ANT can be seen as a goal-directed theory, because it supports an understanding and identification of how and on what grounds people and things become what they are. It highlights the struggles and negotiations between different network components that are needed to achieve a given aim in a stabilization process. The networks are created through different interests in different networks or network components. The changes depend on the resistance of the components' interests in the network. ANT refers to this resistance of an actor-network as the *irreversibility* (Callon 1991) of the actor-network. Irreversibility is described by Walsham as: "…the degree to which it is subsequently impossible to go back to a point where alternative possibilities exist (Walsham 1997, pp. 468). A network made up of irreversible components has to be mastered if a new network is to come into being. The more durable the components, such as scientific truths, economic markets, social factors or machines, the harder it is to change the network (Latour 1992).

In terms of ANT, *inscriptions* (Akrich 1992, Akrich and Latour 1992) are the result of translating one's interest into material form (Callon 1991). Inscriptions can be properties, i.e. features, characteristics, and possibilities inscribed in artefacts, as well as meetings, institutional arrangements, skills, etc. Inscriptions can be of a technical character - for instance, a paper document is light and tailorable - or social (non-technical), like the social collaboration in reading and writing medical records. According to Akrich (1992), the notion of inscriptions refers to the way artefacts embody patterns of use.

How inscriptions will be used in a socio-technical network cannot be foreseen. When the inscriptions become "institutionalized" (Monteiro and Hanseth 1995), i.e. tacit and explicit routines and conventions develop around their use within an institution, they may also become difficult to reverse. For instance, the institutionalized inscriptions of using the paper medical record have become most difficult to reverse. This does not mean that it is impossible to translate the paper request into an electronic request. It just means that it is never possible to know how much effort and resources it will take to transform the use of paper requests to the use of electronic ones. However, by studying the use of paper requests, we as designers and scientists can understand how the inscriptions influence the radiologists' performance, and on what grounds a radiologist's interrelations in Healthcare are shaped and constituted in a particular way.

Studies of the properties of artefacts, e.g. films and paper documents, in work practices illustrate the importance of understanding how these properties are exploited in work practice (Paper 3; Paper 4).

In ANT, different interpretations of a network can be taken into account. Medical staff may see a network that looks different to the one a patient sees. A basic question in the Actor Network Theory is how a diverse group of actors reach agreement at all; how a social order will establish stability and exhibit robust structural properties. According to ANT, the process of achieving agreement (or a stable network) is dependent on the *translations* (Latour 1987, Callon 1991) done by the actors. This means how actors represent or appropriate the interests of others to their own (Latour 1987). The actor's interests can be translated into social or technical arrangements as a work routine or inscribed in a computer system. On translations, Callon says: "…translations are embodied in round-table discussions, public declarations, texts, machines and bodily skills – the possibilities are endless. The elementary operation of translation is triangular: it involves a translator, something that is translated and a medium in which that translation is inscribed" (Callon 1991 pp. 143). This means that the translation from analog films to PACS images, for example involves: PACS technology as the translator, the practice of reading images as something that is translated and the electronic images as the medium in which the translation is inscribed.

Intermediate perspectives used in the IS field

It is generally accepted that information technology has the potential to support the restructuring of work organization (Mathiassen 1981, Orlikowski and Robey 1991). To try to understand and represent the interplay between humans and technology in order to understand organizational change is a challenge. How to do this in practice is far from obvious. Different researchers have taken different positions within the intermediate perspective: Web Models (Kling 1992); Structuration Theory, as presented in a case study by Barley (1986) and interpreted by Orlikowski (Orlikowski 1992); Activity Theory (Engeström 1995, Gregory 2000); Actor Network Theory (Hanseth and Monteiro 1996, Sandahl 1999). Kling (1992), who was one of the first IS researchers applying this perspective, emphasized the relation between humans and technology, and stressed a theoretical position in which information technology performs and is performed in an intertwined process involving humans, things and conventions in practice. In this view, the technology cannot be separated from information services.

Within the intermediate field, various concepts have been developed to describe the extent to which humans can control technological development: improvisation (Ciborra 1996); cultivation (Dahlbom and Janlert 1996); drifting (Ciborra 1996). The concept of improvisation assumes that technological development is more or less under human control. It is a purposeful human action where thinking and action seem to occur simultaneously (Ciborra 1996).

The designer is the main actor in this perspective. In contrast, drifting implies that there is no conscious human control in technological development. The technology emerges as the main factor. Here, cultivation is here regarded as a position in which humans shape technological development although the humans are not in complete control. This is close to Actor Network theory's perspective on heterogeneous engineering, in which social and technological elements are tied together in the development of technology. These elements define each other by their relationship in a design process.

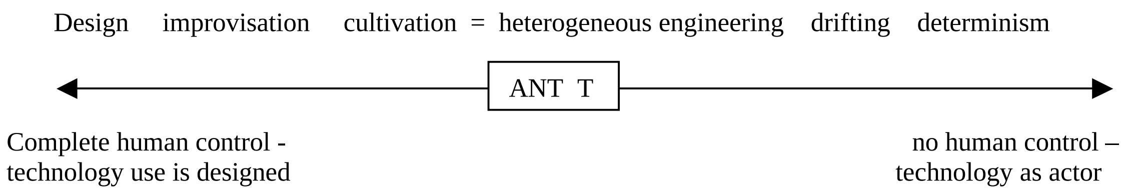

Fig. 1 Concepts for technological development[5]

Organizational change takes place through the relations between humans and technologies. Since these relations are negotiated and not given, the changes cannot be foreseen. This does not mean that, as designers, we fall into a state of uncertainty. It just means that although a technology's properties set particular prerequisites for the interplay between humans and technology, this in itself does not determine the human's interpretations and use of the technology. Humans are able to decide, consciously or unconsciously, how they will respond to the technology. Therefore, in order to know more about how IT shapes, enables and constrains organizational changes, we need to study in detail the aspects, modules or functions of an IS that in practice enables and constrains organizational changes (Monteiro and Hanseth 1995). By studying the way in which the properties of humans and things are linked in practice, we may understand their significance for organizational work - that is, the degree to which an inscription actually succeeds in enforcing a desired behavior. In this way, designers may understand more about exactly which properties are needed to achieve a given aim (ibid.).

An important component in work practice is the technology. This technology is not an isolated artefact, it is an actor in a larger network supporting communication. The technology is designed and controlled by medical managers, IT designers and users, but is also an actor shaping its environment as well as its own future. Radiology work involves heterogeneous socio-technical networks, and the application of the concepts of heterogeneity, network and inscription makes it understandable that the way things are intertwined is not accidental. Instead, the socio-technical arrangement is established over time to fulfill some intentions or aims. I will emphasize how the local PACS are part of a large and open socio-technical network for the whole hospital, and even a shared network for communication between all Healthcare units. This implies

[5] A similar figure is presented in Hanseth (1996).

that the design of PACS may be considered as the design of a socio-technical network.

The reason for using ANT in this thesis has been that it provides theoretical concepts as ways of being specific about the technology and its design and use in medical practice. This has led me to investigate and document work practice elements - both humans and non-humans - as well as processes of translation and inscription, motivations and actions of heterogeneous actors' interests, and the degree of irreversibility of networks and their elements. Investigating and documenting a complex and heterogeneous socio-technical work practice with numerous actors, such as those found in Healthcare, is of course no easy task. ANT supports this process.

Borderline issues

The concept of "borderline issues" (Brown and Dugid 1994) is applied to discuss the importance of unnoticed resources of the artefact beyond what is usually recognized as their regular meaning. According to Brown and Dugid (1994), artefacts have both central and more peripheral properties, and there is a border between them. What is recognized as a central or peripheral property varies in different communities of practices. Some users may see a particular property as central and important, while the same property may be peripheral and uninteresting for others.

Brown and Duguid (1994) highlight borderline resources that constitute a social meaning for a group of people. "The border resources are those resources that are socially and locally shared" (Brown and Dugid 1994, pp. 8) and developed over time as artefacts are integrated into practices and social conventions are developed. The process of integrating and linking entities together is a process of developing a network. It may therefore be postulated that borderline issues arise in the establishment of a network. Communities of practices maintain the borderline resources, and workers often rely on them (ibid.). The meanings are based on the continuous presence of the artefacts in a community of practice. Continuity is needed in order to recognize the artefacts' properties, and a community of practice is necessary for members to share, recognize and reformulate conventions (ibid.). Using borderline issues emphasizes the need to consider the roles of a technology that relates to a particular community of practices in a specific context. When one applies this view to the interconnections between radiological staff and paper-based requests, it becomes clear that the document has several roles in medical practice. All these roles have a particular meaning for medical work and are developed in order to keep the medical work practice together (Paper 3). Figure 2 (below) illustrates that a peripheral resource has a private meaning for an individual, but is unknown to all others, while a borderline resource is locally shared and has a meaning for a community. Finally, a central resource has a shared meaning for everyone.

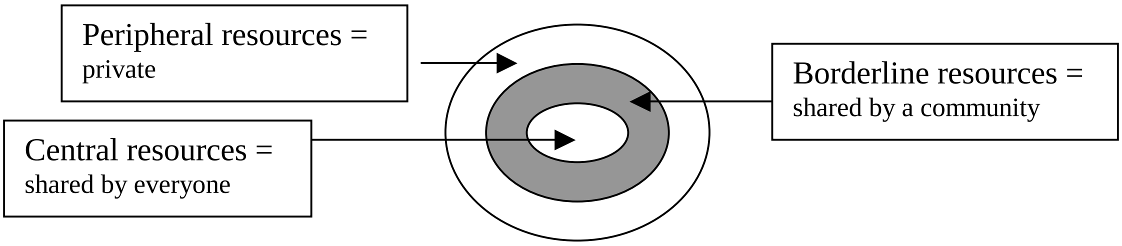

Fig. 2 Relations between central, borderline and peripheral resources in work practice.

If designers fail to acknowledge the borderline resources in the translation from paper documents to electronic documents, this may cause disruption of work. For instance, if the paper request's ability to trigger and even support the coordination of work is overlooked by designers in a translation to electronic documents, the implicit information necessary for the process of triggering and coordinating medical work will be lost as well (Paper 3). When documents become electronic, there will be no paper documents, shelves and tables supporting coordination work in medical practice. The paper documents are computerized; the process of carrying them, sorting them, placing them or using them becomes invisible. There is therefore a lack of implicit information necessary for the coordination of work (ibid.). Focusing only on the paper document's central role, i.e. its ability to share information, designers failed to inscribe the RIS with the more hidden roles of paper documents: their ability to support the awareness, overview and even trigger of work (Paper 5). As a consequence, the Pediatric Radiology Department, Astrid Lindgren's Children Hospital has not become "paperless", which was the initial aim; instead, paper documents were retained in work practice to support the coordination, awareness and overview of radiological work.

The perspective of borderline resources is in line with that of social constructivism, in which the technology is of little importance in organizational change. Although the views of this study differ from the borderline-resources perspective on technology's roles in organizational change, borderline resources have been most relevant to my study, since the conceptual framework of both peripheral and central properties creates a richer basis for understanding and discussing artefacts and their central, locally shared and peripheral meanings and roles in work practice.

I have found the concepts of "Borderline Issues" to be a useful complement to ANT's concept of inscriptions in the understanding of technologies in work. Borderline Issues provides a more detailed way of understanding and talking about the technology, with its emphasis on central, peripheral and borderline resources. In the process of designing information technology designers need appropriate concepts to understand and talk about the technology. The use of these concepts has, in particular, led me to identify and document the use of borderline resources in medical work. Identifying and documenting the borderline meanings of a complex technology, such as the paper request, is no easy task, as they are hidden in links of the artefacts, the users, social conventions and other elements in the work practice. Finally, have the "Borderline Issues" been useful since it highlights how the social and material aspects of artefacts are interwoven, the loss of physical continuity often disturbs social practice. Therefore, it has been important for me to pay particular attention to their interplay.

Technical perspectives

In this thesis, different technical perspectives, e.g. infrastructures, and networks, are applied to analyze my ethnographically collected results. The combination of different technical perspectives and various theoretical concepts is applied to achieve a detailed and thorough understanding of the role of IT in organizational change. By exploring the technologies in use, it is possible to understand how artefacts become embedded in work, and hence suggest factors that one should consider when designing the new technologies in Healthcare to improve their use. In this section the various technical perspectives will be described.

New tools – new technologies

Computers invite us to think of them in different and ways (Dahlbom 1996b), and as they have been radically transformed over the last fifty years, various perspectives have been developed on their meanings in work. Initially computers were machines in the 50s and 60s. The computer was a machine that could efficiently do calculations that humans could not achieve in a lifetime. In the 60s and 70s these machines became data processing machines in industries, banks, etc. "The 80s became the decade of the PC… The success of the PC was due to its use in offices, for spreadsheets, as word processors, and as desktop publishing tools" (Dahlbom 1996b, pp. 31). In the 90s, computer networks became a communication medium (ibid.). By the end of the 90s, many organizations and companies were using information technology in various contexts, as is reflected in e-banking, e-commerce, e-education, etc. Today's network technology connects us all together into a huge world of information and communication.

As the technology and its use have changed, different perspectives on various kinds of technologies have been developed, as mentioned above. There has been a transition from seeing technology as a tool that supports data processing to seeing it as an infrastructure or network supporting interactive communication globally. There is a significant difference between the perspective of closed data processing systems and an infrastructure perspective supporting interactive communication globally. In this section, I will indicate particular differences in these various technological perspectives.

From individual tools to infrastructure and network

When the technology was seen as a machine, rationalization was a strong incentive. The focus was on technology as an efficiency technology. When the PC was introduced, its use became broader, and the technology was viewed as tools (or media) for human activity that could support both communicative and instrumental activities. It was something that could mediate our activity towards other humans or towards ’objects’ (Ehn 1988). Ehn (1988) uses a telephone book as an example of an artefact that mediates communication, and a hammer or an electric drill as examples of artefacts mediating instrumental activities. According to Ehn (1988), an artefact can augment and even replace individual or cooperative human activities.

Over a long period, the focus of IS has changed from the development of isolated information systems towards the integration of large numbers of systems across organizational and geographical boundaries (Hanseth 1996). As technologies were integrated, they became more than tools. They became part of a larger infrastructure, and have acquired new fundamental characteristics that are far more complex than individual tools. In this transformation, information technology has been reconceptualized and classified as (information) infrastructures (Kling 1992, Hanseth and Monteiro 1997, Ciborra and Hanseth 1998). An information infrastructure is designed to support a range of activities: it is a technology built as a layer on another technology, integrated with other infrastructures into networks with no limits. Furthermore, it is shared by and open to a larger community, including heterogeneous entities such as humans, technological components, organizations, and institutions (Hanseth et. al 1996). It links humans and technologies together over distances that span a number of activities; it requires the uniformization of many existing practices and systems (Monteiro and Hanseeth 1995). Another difference between the isolated information systems and infrastructures is that the latter are “…developed and changed by several independent actors without any explicit coordination” (Hanseth and Braa 1999, pp. 190.). An example of such an infrastructure is the Internet. An important aspect of such an infrastructure is that it is built on standards: social and technical, developed over a long time. In this thesis the infrastructure is seen as the cooperation between the radiologists and their customers including: the physical radiological paper requests and the reports (which the order forms are transformed into during the examinations) and the images: the daily meetings, and the ad-hoc conversations.

It is important to stress that the view of technology as something that could mediate our activity towards other humans or towards objects is, and has been, an essential contribution to our view of technology in use. However, as technology emerged as an infrastructure and network supporting interactive communication globally, new perspectives considering interconnections and links in widely connected networks were developed. Hence, infrastructure and socio-technical network perspectives were developed. These perspectives differ from the tool perspective. Applying these perspectives, it is possible to understand artefacts linked together into networks and infrastructures crossing the boundaries between communities. This implies that technologies could be understood both internally, that is, in terms of their interconnections and roles they play within a community, and externally, in terms of the way they mediate relations among communities.

When viewing artefacts from a network perspective, we are required to take the artefacts into the social world, and give them the attention they deserve in a process of understanding their roles and meanings in work. In this way the network perspective says something about how actors and artefacts are intertwined. This view does not separate artefacts from the social world. Instead, it takes the social meanings of the artefacts in practice into account. The network is socio-technical in that the humans and non-humans are intertwined, and together they create the community of practice. Anthropologists of technology, such as Latour (1987), and Akrich (1992), have described the nature of technical artefacts: how they take their significance from the social world, while they mediate our interactions with that world.

From isolated use to domestication

As the network technology emerged, information technology became more than isolated tools. It was no longer a tool or a medium for one particular purpose. Instead, it developed various applications and functions shared across different communities for different purposes. The design of a shared and distributed network is much more complex than that of isolated tools, and cannot therefore be performed according to the principles appropriate to isolated systems. It needs to be designed by several independent actors without any explicit coordination. The main coordinator is the network itself (Hanseth and Braa 1999). “These networks became environments that people work in, socialize in and in fact live in. In our world, technology has become much more than a gadget or a tool; technology has become an expression of our interests, an implementation of our values, an extension of ourselves, a form for our lives” (Dahlbom 1996, pp. 36). What used to be an isolated machine has developed into numerous integrated information technologies, used in diverse areas for many different purposes of various people, turning into something that continuously supports each and one of us in our daily lives. Humans and technologies have become intertwined; you cannot understand one without understanding the other.

Every day we see how artefacts or technology form part of our lives. For example, in the morning I read the news on the Internet in the kitchen. While driving the car to work, I talk on the phone. In the evening my children play video games, while I check my email. “IT has moved beyond the workplace and into leisure, entertainment, games and our homes” (Monteiro 1998, pp. 249). These technologies induce me to behave in a certain way in my life. I stop at red light even if I have promised someone to be somewhere else at that time. In this way, we are not machines that always act rationally, but the artefacts impact us in our work, and they have different roles for different people that have to be taken into account. For me, email might be something different to what it is for another person, just as its meaning for me changes over time. Designing stand alone information systems, there are not as many contexts and circumstances that needs to be considered. In a way, humans and non-humans are boxes in flow-charts that can be moved around. In the design of an actor-network the setting is much more complex, more contexts and circumstances needs to be considered, just as it must be considered that people do not have to act in the manner prescribed. The outcome of technology use can therefore never be foreseen. The way that network technology, such as electricity, television, and computers becomes "domesticated" (Silverstone and Haddon 1996), that is, a natural part of our daily activities used in a wide variety of contexts for many different purposes; at work, at home, for pleasure, for communication, etc., is far from straightforward. But as network technology turns domesticated it becomes so self-evident that it eventually becomes "invisible" in everyday life and use. According to Monteiro (1998), it is a process in which technology transforms itself – and social order – as it gradually seeps into the pores of our life. The process of domesticating a new technology resides not only within the designer of the technology, but also within the users and their public perception of the use of the technology (ibid.). The process in which the technology becomes domesticated is further explored in the next subsection.

Creating an Infrastructure by developing Borderline Issues and Domesticating the Technology

As mentioned above, the concept of borderline resources is applied in this thesis to discuss the importance of the artefact's unnoticed resources beyond what is usually recognized as its regular meaning. Using borderline resources also emphasizes the need to consider the roles of a technology that relates to particular communities of practices in specific contexts. When one applies ANT's focus on the interconnections between radiological staff and paper requests, it becomes clear that the paper request has several locally shared roles in medical practice. As an illustration, this is briefly presented below; for more on this issue see Paper 3.

The central role of the radiological examination request is to support the sharing of information. When the request is received in the radiology department it contains administrative information, e.g. patient ID, referring physician and medical unit and examination requested. It also contains medical information; patient history, indication for examination and differential diagnosis to be considered. In the radiology department a variety of further information is added to the request, e.g. technical examination data, drugs given, patient condition and preliminary evaluation/diagnosis. To add another function to the request, different colors are used to indicate different degrees of priority. Over time, locally shared resources associated with the request have developed. For example, a transporter places the written request on an "in" shelf in the administrative area at the radiological institution. Later, as an administrative staff member is passing by and sees the paper document, she knows there is a patient to register and book. She knows this since conventions and rules have been developed around the placing of the document on the "in" shelf. The medical staff uses the paper document to support *coordination* of work in this way. After patient registration and booking, the administrative staff member places the paper document on a pile outside the image production area. When a radiographer glances at a pile of written requests placed by the administrative staff, the paper documents are used as a *medium* that gives the radiographer an overview of the workload to be carried out. During image production with the written request at hand, the paper is used to support essential information sharing between different medical staff members. Finally, the written request is used as a medium for communication between the radiology department and the requesting unit when a transporter returns the request with the diagnostic report added to it.

The description above illustrates how the paper request's properties, the medical staff, the conventions and other elements in medical practice were linked in medical work. In this process, at the radiology department, the examination request was developed to support coordination work, awareness of medical colleagues' work, and an overview of work (Paper 3). As the technology developed these borderline resources step by step, it emerged into an infrastructure within the radiological communities of practice. Over time, as the paper request developed its various meanings in different contexts for different people, its use became diverse and self-evident in medical work. It has been a long process, in which the socio-technical radiological request became customized to the needs of medical work and vice versa. This evolutionary process can be described as a process of technology domestication. Infrastructures, such as the radiological paper request are constructed by linking artefacts together and thereby making them interdependent. This happens partly by linking their peripheral issues together, for instance, by combining requests and tables visibility and using them to support coordination work. But infrastructures are to a large extent constructed by linking artefacts together by means of their borderline issues. It is suggested that in order for a technology, such as the paper request, to become an infrastructure, it needs to be domesticated and develop borderline meanings, as illustrated above, in work.

For a paper request to develop these various meanings in work takes time. It is conducted in a process of “deep ecological penetration” (Joerges 1988), meaning that over time it changes the fundamentals of a work practice, e.g. it transforms work life – it changes the way we think of and perform work. It relies on a complex interrelationship between the humans and the properties in the technologies, the work practice and the Healthcare community as a whole.

Because of the limited use of PACS today, it could scarcely be considered as an infrastructure technology as defined in the previous section. What would be required in order to develop it into an infrastructure? Firstly, PACS would need to be integrated with many other technical components, e.g. RIS, HIS, other PACS, electronic lab reports. Secondly, over time borderline resources would have to be developed around its use. PACS could, for instance, offer free text search and hypertext links to related information. This search facility could give PACS an important meaning for research work. Furthermore, PACS could also be linked to a patient site. The patient could log on to the custom site to learn about the examination, the radiology department, or find contact information making it possible to call the radiological unit directly. In this way, PACS would develop a new significance for the patient. Many different communities could, theoretically, use PACS for many different purposes. The potential process during which the PACS develop their manifold meanings in practice is a process of PACS domestication.

Research Approach

This research applies an interpretative approach. This section describes why this was chosen in the light of the research problem, the setting and the theoretical background described in previous sections.

Interpretative Field Research

Klein and Myers (1999) have recently argued that the principles for interpretative field research have their background in the hermeneutic circle. This means "…that all human understanding is achieved by iterating between considering the interdependent meaning of parts and the whole that they form" (ibid. pp. 72). In my interpretation of medical practice, I have developed an understanding of the local links between documents, shelves and tables in medical practice in order to contribute to the entire radiological work practice: just as the understanding of the radiological practice has improved my understanding of the entities included in the radiological work practice. "Interpretative research can help IS researchers to understand human thought and action in social and organizational contexts,…it has the potential to develop deep insights into information systems phenomenon including information systems development" (Klein and Myers 1999, pp. 67).

Several other concerns, beyond the interdependent meaning of parts and the whole, of interpretative field studies relate to my overall research question – *how can we improve the design, implementation and use of PACS by studies of the complex interrelationship between the medical staff and the technologies, the work practice and the Healthcare community as a whole?* Firstly, the point of departure of interpretative field studies is that it is more concerned with the interpretation of meanings than with the discovery of "false preconceptions" (Kaplan and Maxwell 1994). This is also a primary concern in this thesis: complex interrelationships are identified and analyzed in order to inform the design of improved IT use in healthcare. Secondly, another concern of interpretative field studies is that organizations are not static and that the relationship between people, organizations, and technology is not fixed but constantly changing (ibid.). This is also a basic premise of this research, which views the understanding of interrelationships in work as a never-ending process, since these interrelations are dynamic.

Finally, a further key point of interpretative field research is that theory plays a crucial role (ibid.). One uses theory as a device, to view the world in a certain way. In this thesis, I have used ANT as a guide to designing the research as well as to collecting and analyzing my data. In addition, I have applied borderline issues and various technological perspectives for the same purposes.

Many interpretative studies have considered the meaning of IT use in organizations. These studies have developed theories of IT design, and have developed new concepts surrounding IT use in organizations (Suchman 1987, Zuboff 1987, Orlikowski 1991, Walsham 1993, Ciborra and Lanzara 1994, Hanseth et. al 1996). Hence, interpretative research has emerged as an important methodology in the information system field (Walsham 1993). Doing interpretative research is like putting the pieces of a puzzle together, except that the pieces are not all given but have to be partially fashioned and adjusted to each other.

Of the interpretative field studies, I chose "Ethnography". The next section describes in more detail why and how this was done.

Ethnography

The reason for choosing ethnography was that the objective of my empirical work was to improve the understanding of technology use in medical practice, both before and after the introduction of PACS in hospitals. This is necessary because this thesis focuses on the replacement of analog films by digital images. My hypothesis is that an understanding of different ways of using technology will generate improved and new ideas for IT use in many health-care contexts. This is related to my hypothesis that major problems in the design of PACS are associated with difficulties in obtaining adequate knowledge of the medical work practice, informing designers of this, and organizing the process of "IT development, implementation and use". When I refer to the medical domain, my analysis is not concerned with the individual and the system so much as with the interactions between different medical staff as they conduct and coordinate a range of tasks and utilize various technologies in health-care work.

Another reason for choosing an ethnographic approach is its ability to make medical settings visible, to produce detailed descriptions of the radiological activities within medical contexts. This fits in well with one of the major principles of interpretative studies, which is an emphasis on making the intellectual basis of the research as transparent as possible to the reader, with thorough empirical descriptions. Ethnography is concerned with describing a certain domain, such as a working day, as seen by the people involved (Hughes et al. 1994). Since I aimed to present a picture of medical work as seen and understood by the radiological staff, ethnography has represented a fruitful point of departure. Ethnography supports an in-depth real-life study of the processes taking place.

The ethnographic research method has recently become recognized within the IS field (Suchman and Trigg 1991, Bowers et al 1995, Bellotti and Bly 1996, Button and Harper 1996, Button and Sharrock 1997). Many IS researchers emphasize the understanding and representation of the real work practice, stressing that the way that people work is not always apparent (Hughes et al.

1994, Suchman 1995). Suchman (1995) pointed out that the importance of making work visible for systems design is to develop technologies that are more appropriate from the point of view of those who will be using them. As designers, we can easily fall into the trap of allowing our view of medical work to become too simplified and stereotyped because we are in practice quite distant from it. Before I present the ethnographic methods used in the different studies in more detail, some introductory studies I did will briefly be described.

Introductory studies

My research on IT use in Healthcare started in spring 1993. Qualitative case studies and inquiries were used as the approach in three introductory studies. This introductory research gave me an overview of computer use in radiology departments in Sweden and provided leads for future interesting case studies. It also helped me to establish new contacts with people working in Healthcare, in addition to the contacts I already had. Most importantly, during this process the overall research ideas emerged: to investigate why the PACS implementations had been problematic, and why health-care institutions have so far not achieved the great efficiency improvements that medical staff initially expected from the use of PACS.

The papers in the introductory phase have formed part of the process of writing the thesis, since they contributed to my overall understanding of medical practice and should therefore also be mentioned:

- Lundberg N. (1993). Computerization of Radiology Departments. Proceedings of the 16th IRIS, pp. 252-259.

- Lundberg, N. (1996). How Network Technology Changes the Work Process at a Radiology Department. Proceedings of the 19th IRIS, pp. 175-195.

- Lundberg, N. and H. Tellioglu (1997). Impacts of the Re-Engineering Process on Radiological Work. A comparative study between traditional/non-PACS-based and networked/PACS-based radiology departments in Austria, Sweden, and Denmark. Proceedings of the 15th International EuroPACS Meeting, Pisa, pp. 251-255, September 1997.

- Lundberg N. (1998). Integrating Various Learning Contexts in a One-Year Medical Informatics Program. International Journal of Medical Informatics, pp. 117-124[6].

[6] An early version of this paper was published together with Stefan Sallerfors at the 1997 IMIA WG1 Conference, 6th International Conference on Health and Medical Informatics Education, in Sydney, Australia.

The first ethnographic study

The first empirical fieldwork started in October 1996 on a small scale, but was later followed by a larger study in 1998 at the Pediatric Radiology Department, The Queen Silvia Children's Hospital, Gothenburg, Sweden. This is a conventional, non-PACS radiology department, which conducts about 40,000 examinations per year. During the study I conducted about 25 open-ended interviews lasting from half an hour to two hours. Some people were interviewed a number of times. In addition, 30 hours of observation of medical staff were carried out. The interviews and observations involved radiologists, clinicians, administrative staff, radiographers, typists and file-room staff. The observations were made by following the examination request around in the work practice. Although it is a delicate matter to ask medical staff questions during patient treatment, during or after patient diagnosis or intervention I also asked about their work along the way. I took notes, and when it was possible I recorded the dialog on a tape recorder. The notes as well as the tapes were transcribed, and confirmed by a radiologist or other relevant medical staff. In addition, when questions arose during the analysis of the material, I made a number of additional phone calls. During these calls I took notes.

The second ethnographic study

The second study at the Thoracic Section, Radiology Department, Sahlgrenska University Hospital, Gothenburg, Sweden, started in October 1997. This was one of the few radiology departments using PACS at that time in Sweden. The Thoracic Section is one of three sections at the Radiology Department, where the remaining two are uro-gastro and neuro-skeleton. In all, the section conducts some 40,000 examinations per year. Several different qualitative research methods were used: workplace video studies, open-ended interviews, interviews articulated by the illustration of video documentation, observations, and an integration of discussion interviews and observations of diagnostic practice and social interaction. A total of 43 hours of video documentation, more than 45 hours of observations, and 22 interviews were conducted. Each interview lasted about an hour and a half, and some participants were interviewed more than once over the period of study.

This fieldwork was conducted together with Ph.D Magnus Bergquist, who is an ethnographer. During the fieldwork we discussed and explored the meaning and ideas behind the different methods used in the study (Bergquist and Lundberg, 2000). Some of these ideas are presented in this section.

During the workplace video studies, the entire diagnostic practice was recorded by one camera and the RIS processing by another. A camera was placed on the ceiling behind the radiologists, and data were collected without interrupting or interfering with the radiologist in practice. This gave us the possibility to reanalyze the original data and look for new details. Carrying out interviews while showing the video documentation made it easier for the radiologists to describe and talk about the medical staff's work practice, thus facilitating our understanding of the practice. It contributed to an in-depth insight into the radiologists' reflections on their work. It provided an opportunity to clarify misunderstandings of work practice at an early stage. It also enabled the users to look at their work from a distance and analyze their work in a different way, which generated fruitful discussions about the design of information technology. The open-ended qualitative interviews created a broader and deeper knowledge of the medical staff's way of experiencing and understanding their work situation and their entire role as professionals. It highlighted the problems and interruptions in work. This was also a method of understanding how the radiological staff experienced differences between old and new work practices. The majority of interviews were recorded and later transcribed. Occasionally we also took notes that were later transcribed. Observations were carried out in order to gain an understanding of the complexity and multiplicity of the work. It was a way to illustrate how work was related to time and space, and to grasp the mobility and flexibility of work in different situations and contexts. It focused on practice rather than reflection. We observed diagnostic work, interventions, various interdisciplinary meetings and conferences, coffee breaks and teaching sessions, in groups and in individual settings. Following the ethnographic tradition of managing the data, both authors scripted a narration of what was going on at each observation. The material was thereafter jointly compared and analyzed.

The integration of discussion-interviews and observations was a heuristic way of going about the data collection: a way to test and extend the questions in focus and to extend and find new angles of approach. Hypotheses were developed, tested and thereafter confirmed or rejected. This was a way to find interesting themes for further observation and/or interviews. The combination of ethnographic research methods made it possible to focus on both details and overall context.

The small-scale studies

The empirical data collected from the larger ethnographic study at the Radiology Department, Sahlgrenska University Hospital, was followed up by a study at the Pediatric Radiology Department, Astrid Lindgren's Children Hospital, Karolinska Hospital, Stockholm, Sweden in February and July 1999. I also conducted a study at the Radiology Department, Örebro Medical Center Hospital, Sweden, in July 1999. The radiology department at Astrid Lindgren's Children Hospital conducted about 50,000 examinations per year, while the radiology department in Örebro conducted about 85,000 radiology examinations per year. More than 18 hours of observations and 16 hours of open-ended interviews were conducted, with some participants being interviewed more than once over the period of study. I interviewed staff from the PACS suppliers who were on site at the hospital, radiologists, radiographers, clinicians and computer technicians. Some of these interviews were conducted as a comparison with the main study, but also to clear up points that came up under the analysis as well as during the interviews. I took notes, and when it was possible I recorded the dialogue on a tape recorder. The notes as well as the tapes were transcribed, and in the majority of cases confirmed by a radiologist or other relevant medical staff. When questions arose during the analysis of the material, I made a number of additional phone calls. During these calls I took notes.

The Five Papers

The research on IT use in Healthcare started in August 1996. Several ethnographic studies exploring radiological work practice before and after PACS were carried out between autumn 1996 and spring 1999. To get more precise information on the problems involved in designing and adopting PACS, the studies were subsequently followed up with repeated interviews with the radiological staff involved in the studies. The aim of the follow-up was to improve my suggestions and to evaluate their general applicability to Healthcare. Below, I summarize and relate the five papers that approach the research issues of the thesis.

Paper 1: "Impacts of PACS Technology on Medical Work"
In this paper I explore and illustrate the impact of PACS on radiological work practice and on the interdependencies in work. To explore this impact, I choose to emphasize artefacts and their properties in the interrelationship between people and things in the conventional work practice and the PACS-based work practice. The radiological work may be divided into a macro- and a micro-level. The macro-level includes a sequence of tasks: the scheduling of a patient, registration in the radiology department, image/film production, image/film saving and archiving, combining images/films with RIS data, image/film distribution to radiologists, image/film prefetching, display of old images/films, image/film analyses and diagnosis, reporting, transcription of reports, checking of transcribed reports and sign-off, sending of reports to clinicians and clinical image/film demonstration. The micro-level includes the performance of individual tasks – how are they performed? By whom? In cooperation with whom? Where, and when? This paper suggests that when analog films were replaced with PACS images, the achievements in work, on a macro-level, were insignificant. The traditional sequence of activities to carry out work remained unchanged. That is, although films were produced in a different way, the steps in the radiological work, starting with the patient registration, continuing with the patient examination and ending with the evaluation and diagnosis of films/images, remain unchanged. However, the performance of most of these activities is changed, i.e. substantial changes in work were identified on a micro-level. For example, all activities related to the production, retrieval, placement, communication and archiving of x-rays were transformed, as these were computerized in PACS work. It was found that not only technical devices were

integrated, but also the people, work practices and organizations. Analog films are not simply replaced with electronic images: film-production processes are replaced with PACS-production processes. This makes the implementation and adoption of PACS technology particularly challenging. In addition, the changes in the distribution and division of labor were obvious. Working with PACS transforms the radiologist's role in work. For example, the radiologists become their own assistants, secretaries, and archive personnel. One has to keep in mind that the relation between communities of practice was very clear in the old network, where "a doctor was a doctor and a nurse a nurse". This has become less clear in the PACS network, where a radiologist can position films and write reports, but the secretary cannot diagnose an image.

Finally, it is suggested that electronic lists[7] – a simple technical solution used to support the management and organization of individual as well as interdisciplinary work – have properties with the potentials to change the prerequisites for collaborative work. Lately, some electronic lists, e.g. to-do lists, teleradiology lists, teaching lists and interdisciplinary meeting lists, have been introduced in radiological practice. They have been developed as an important coordination technology within medical work. However, the lists are not used in a way that fully exploits their potential. Electronic lists create new possibilities in the performance of work. Having this potential, they could rapidly grow and take on a more central role in the large and complex health-care organization. The use of lists shows how practical application reveals new properties of the technology that in turn may develop new ways of using the technology. This illustrates that the technology has the potential to improve efficiency in work. It is, thus, important to explore coordination, and the technologies supporting it in work.

In order to understand why the achievements in work, on a macro-level, were insignificant, I looked into the sequence and coordination of radiological work in more depth in Paper 2.

Paper 2: "Understanding Complex Coordination Processes in Healthcare"

In this paper, complex coordination processes at radiology departments in Austria, Denmark, and Sweden are analyzed. To enhance the understanding of coordination work, we focus on different interdependencies between work activities. In the process of designing information technology to support coordination processes in Healthcare, designers need appropriate concepts to understand and discuss technology. This paper suggests that various interdependencies have different properties, which in turn have different coordination dimensions. We refer to these dimensions as *predefined* and *situated coordination*. We also suggest that in designing coordination technologies, designers should consider ways to inscribe the IT with features that fit the properties of various kinds of coordination work. This means that there is

[7] A "list' is simply a desktop-folder that for instance is used to support the management and organization of interdisciplinary meetings between clinicians and radiologists.

a need for different kinds of coordination technologies, because the predefined coordination is process-oriented and reiterative. Predefined coordination calls for a technology that aligns and supports the triggering and control of activities guided by organizational formal structures. While the situated coordination is unexpected, unique and unfolding, it calls for a technology that supports improvised coordination according to unfolding events and contingencies. Furthermore, it is suggested that designers should find a way to smoothly integrate the technologies supporting the various kinds of coordination work. To sum up: this study has shown that there are many different kinds of coordination work supported by several diverse coordination technologies in medical practice. The complexity of coordination work makes the design and implementation of coordination technologies in medical practice challenging. In order to inform the design of complex coordination technologies, in Paper 3 I thoroughly explore how the paper request, as a coordination technology, is used in medical work.

Paper 3: "What do artefacts mean to us in work?"
This paper emphasizes improving the understanding of collaboration and coordination work practice by focusing on artefacts' roles and meanings in work settings. To do this, we explore artefacts' peripheral properties and borderline issues, and identify how they become common resources within a community of practice. The paper illustrates the use of different properties in various settings. It shows that as the context changes, some properties become more central while others become more peripheral, just as all artefacts have features that are more or less central or peripheral. As an example, we show that paper requests are active in the sense that they are necessary for information sharing, but also active in a way that coordinates, supports awareness and even triggers or initiates medical work. This paper suggests that it is difficult for designers or other outsiders to recognize artefacts' border and peripheral roles and meanings, due to their highly local establishment. We also suggest that in designing information technology it is important to be aware of these peripheral and border meanings and roles within the medical work practice. When the peripheral meanings and roles of paper requests are overlooked in a translation, some of their resources disappear, and work practice may break down. The study suggests that when paper requests are replaced, we also remove the old technologies' "hidden" meaning and roles that, over time, have become necessary for the radiological practice and hence must be considered in the design and adoption of information technology, such as RIS. To translate paper documents into electronic documents is a challenge. In order to facilitate this translation, in Paper 4 we thoroughly explore how the paper request, as a coordination technology, is linked with human actors and various technologies within the radiological practice and the Healthcare community as a whole.

Paper 4: "Designing Work Oriented Infrastructures"
In this paper we explore how the artefacts and technologies are linked together and how technologies and work practices are interdependent as well as how

distributed work practices are interconnected. For example, how the paper request is linked to the table, typewriter, archive, shelf, trolley, etc., and how the paper request is linked to the patient scheduling, image production, diagnostic and reporting work practice, just as these work practices are interconnected. This illustrates that artefacts are not used in isolation, but together with many other artefacts in practice. We, as designers, should not see artefacts, such as paper documents, as an isolated technology, but rather as an infrastructure technology. This also implies that the information technology should not be seen purely as technology, but rather from a perspective where the technology cannot be separated from social and other non-technological elements. This paper suggests that the more resources linked to the infrastructure, the greater the probability of "successful" resistance to translations. We also suggest that designers need to consider various factors in the design, implementation and adoption of a new infrastructure: 1) the larger the number of actors communicating, or the larger the number of components linked, the more important are standards. On the other hand, the larger the network implementing a standard, the harder it becomes to change the network. 2) The larger a network becomes, the harder it will be to coordinate all actors' actions. 3) Changing a network from one standard to another over a longer period means that different parts of the network are incompatible during that period. 4) To succeed in establishing a new network, a new practice must be established. The new practice must match the old during the transition period. For example, this implies that the existing structure constrains how the new one can be designed. 5) The transition from one infrastructure to another requires links and interoperability across inconsistencies. 6) To achieve the potential and "real benefits" of a new infrastructure will take time.

The results from this paper point to factors that explain why the achievements of PACS and RIS, on a macro-level, so far have been less insignificant than expected, as illustrated in Paper 1. The challenging factors emphasized in this paper illustrate that the complexity and numerous links in medical practice make it hard for designers to do anything else but reinforce conventional ways of working and communicating. This does not mean that effects cannot be obtained on a macro-level – the medical network can be changed. One can, for instance, apply a view where smaller parts, sub-networks, are replaced by new ones, while the new sub-network works together with the larger network. Two sub-networks can be linked through simple interfaces. These interfaces can be taken care of by "gateways" (as defined by Hanseth 1996). Gateways enable various communities to apply different technical solutions that serve various medical departments, but at the same time enable them to communicate and interact independently of differences. The success of such an approach depends on the identification of sub-networks that, firstly, are small enough to be changed in a coordinated process; secondly, have such simple interfaces to the larger network that these interfaces between the new and the old are manageable. In this evolutionary process, the changes are made through a series of steps. This opens a wealth of possibilities in which technical components are linked together with human actors and various technologies within the radiological practice and the Healthcare community as a whole.

It is suggested that the design of PACS could be improved by considering these technologies as *work oriented infrastructures.* This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. Regarding PACS as a work oriented infrastructure as opposed to the universal service infrastructure e.g. railroad, highway and power infrastructures, has taught us some lessons about the design of electronic radiological infrastructures. We conclude that these infrastructures are, and should be, designed and implemented primarily by their users based on their actual use of the technology. We concluded that these infrastructures are, and should be, designed and implemented primarily by their users (and in use). The infrastructure should be built in a piecemeal fashion over a long period – new elements are added to the existing infrastructures and parts are improved or replaced by new ones. The work oriented infrastructures are constructed by linking artefacts together and thereby making them interdependent. A large scale infrastructure emerges as artefacts are linked together and the work of large communities of practice share their meanings through conventions and rules. Shared conventions and rules, i.e. the fact that the paper request form must be placed on a particular place at a table in order to communicate to the radiologist that there is a patient to be diagnosed, are of significant importance for the conduct of medical work. It is of great importance to in a similar way develop shared conventions and rules related to the use of electronic work oriented infrastructures as well.

In the design of technical standards supporting communication in large heterogeneous organizations, such as Healthcare, a prototype-oriented strategy or an evolutionary one may be applied. In such processes the application is developed through a series of versions, where each version is in use for a period, and the next one is developed based on the experiences with its predecessor. In order to inform the design of the prototype strategy’s potential in the design of PACS, I explore this bottom-up approach in Paper 5.

Paper 5: “Standardization in Practice – Examples from Healthcare”

In this paper, we investigate and explore particular consequences of standardization strategies used to develop electronic standards in Healthcare, focusing on the consequences of electronic standards for communication work. The two standardization strategies analyzed are the *specification strategy* used to develop electronic medical standards that PACS are based on and the *prototype strategy* used to develop Internet standards that various medical intranet applications are based on. Against the background of the standardization strategies applied, the paper analyzes how PACS have developed into “local” systems within the radiology department when it was initially intended to support communication between different medical units. This paper suggests that the prototype approach has several advantages over the specification-driven one. It illustrates that the applications based on Internet technology satisfy user needs, as the specifications of the standard specifications are already in operation. The specifications are “correct”, as they have already been implemented. In preparing specifications, first, there will always be many errors that will only be discovered during implementation. Further, the Internet standards are smaller and simpler than the electronic medical standards, as early implementations will skip most “nice to have” features. This makes the Internet applications, based on the Internet standards, easier to change as the users’ need change. Internet applications have proved to be flexible enough to adapt to local needs, yet robust enough to maintain a common identity across sites. They have the potential to grow and meet the challenges of interoperability and collaboration between heterogeneous networks of people and things. Each version is in use for a period, and experience with it provides a basis for developing the next one. There are fewer regulating, institutional arrangements influencing this process. The obvious limitations of the specification strategy used to develop electronic medical standards make the design of PACS most problematic. The way that PACS are intertwined and eventually embedded in work practices and organizations is not an isolated procedure that can be specified in advance, but the consequence of a complicated pattern of medical activities. This pattern integrates not only technical devices, but also people, work practices and organizations. It is thus impossible to foresee all the prerequisites of the technology before it is used.

In sum, it was found that computer systems based on different electronic standards intervene in work in different ways, and that they do not always intervene in the ways in they were initially intended. For example, the PACS based on the DICOM standard have primarily attained a local role, although its initial aim was to support universal image communication within Healthcare. On the other hand the intranet application based on the Internet standards primarily not designed for this particular purpose has come to support communication of images and reports within the heterogeneous hospital network.

Informing Design – To Improve PACS Use

In this research, empirical studies of conventional and PACS-based radiological work practice were performed. Knowledge of the conventional work practice is a prerequisite for understanding the resources that PACS should replace in a translation from analog films to digital images. The idea of viewing technology in the context of the workplace is an accepted approach within the CSCW and IS fields (Greenbaum and Kyng 1991, Ehn 1988, Suchman 1987, Monteiro and Hanseth 1995, Sandahl 1999). In this section I summarize the main points from the introductory chapter and the five individual papers, emphasizing the overall aim of informing design regarding possible ways to improve PACS use within Healthcare.

Prerequisites for a technology transformation

The objective of our empirical field studies was to understand the medical "world" that we, as designers, were involved in changing. Therefore, I studied how individuals, artefacts and individuals, and various artefacts and technologies were linked together. The interdependencies of technologies and work practices were illustrated. For instance, all groups in the radiology department are linked to the X-ray films in their work: radiologists use films when diagnosing patients, clinicians use them when treating patients, radiographers use them when evaluating the film quality, secretaries communicate them to radiologists, etc. The studies showed how different work practices, which may be separated locally, are interconnected (Paper 4) within Healthcare. For instance, the aspects of work practice involving administration, image production, film quality evaluation, diagnosis and reporting are all interconnected within the radiological work. Finally, the film fits together with other artefacts. For instance, the film fits the light board, envelope, shelf, table, trolley, etc. and these technologies together become resources in medical work. The different humans, artefacts, conventions, tasks, work practices and organizations are linked together and adapted to each other to make the overall process smooth and efficient (Paper 4). If one of these components is transformed, for instance in the transition from analog films to digital images, all its links in practice will also be transformed. This is a challenge because it means that PACS technology translations not only replace analog films with electronic images, but entire film-production processes with PACS-production processes. People, work practice and organizations are other essential entities involved in the transformation process (Paper 1).

How the transformation from analog films to digital images should be carried out is far from evident. One way to facilitate this transformation process may be to obtain a better understanding of the use of artefacts, e.g. films in medical work. This study strives to achieve this by emphasizing the properties of the film that are used in work. The film's properties, in contrast to digital images, are dark physical objects that come in definite forms. It was found that artefacts' physical properties play a crucial role for their use in medical work (Paper 1, Paper 3) For instance, the diagnostic work is triggered as the assistant radiographer positions the films on a predetermined light board. The radiologist who is to carry out the diagnosis will see the positioned films and then perform his task. A glance at the light board as he enters the diagnostic area gives him an overview of the image interpretation work to be done, just as it makes him aware of the workload to be carried out. The sight of the films on the light board triggers the radiologist to take action (for an analysis of how paper requests are active elements in the relationships among people and between people and their environments, see Paper 3). This illustrates that the X-ray films have developed locally shared meanings in many contexts and activities beyond their regular meaning. It was found that the films generate awareness in work as well as trigger of radiological work. These meanings were partly developed on the basis of the film's properties' as a physical object. This example illustrates that designers need to be aware of the close interrelations between artefacts (Paper 3), e.g. films, light boards, tables and humans. They also need to consider the special meanings of film properties within a work practice, beyond the regular meaning of the film as the primary "tool" for the radiologist's diagnoses of a patient (Paper 2). By studying the properties of artefacts such as films and paper requests in socio-technical contexts, we get an idea of the essential resources and prerequisites for the work being done. This helps us to understand what resources the PACS should replace in a transformation, even if there is no guarantee that they will be used in the way as expected.

Identifying sub-networks and linking them through gateways

As the medical network is very large, we, as designers, cannot coordinate all actors' actions in a "big bang" transformation process. However, there are other ways to change a large and complex medical network. For example, it may be possible to change the whole medical network in a process where smaller parts, sub-networks, are replaced by new ones while the new sub-network works together with the larger medical network (Paper 4). From this perspective, a sub-network is seen as a unit consisting of two or more components linked in a larger network. For example, a sub-network may be a radiologist diagnosing images in the radiology department, or the radiology department communicating patient diagnoses to requesting units within the hospital. Two sub-networks can be linked through simple interfaces. These interfaces can be created using "gateways" (Hanseth 1996). Introducing gateways is an attempt to maintain medical work practices that are challenged by inconsistencies in this transformation. A single medical network may be in many different stages of transformation as long as gateways are introduced to maintain communication between these sub-networks. Applying this evolutionary approach we, as designers, take the existing network, the "installed base" (Hanseth 1996), as a design starting point (Paper 4), and then change sub-networks step by step in the larger medical network, until finally the entire hospital has been transformed. In this way, the large and complex medical network may be changed over a long period.

Identification of sub-networks is illustrated below, to highlight the use of various gateways. The steps suggested are the "general" transformation steps implemented in Healthcare. Much emphasis has been attached to the transformation steps as such, but little attention has been paid to the question of how to maintain the communication between these units, independently of differences within the larger medical network. For this reason, this section focuses on the importance of gateways.

Transformations from films to images have presented a challenge. Three major sub-networks to be changed can be identified. The first sub-network is the radiology department. The second sub-network is an extension of the first one, to include the clinical departments. A third sub-network also includes the external regional units that refer patients to the radiology department for examinations.

The first transformation process involves the replacement of the film-creation process with the PACS-creation process. This is of course the most complex one, but it is also a prerequisite for the translation of any of the other sub-networks. A problem arises because many of the links in the network are based on analog films. For example, if the requesting clinician specifies that the images taken should be sent together with the report, paper copies or analog films will be printed on a laser printer and put in the mailbox accompanying the written report to be picked up by a messenger. The interface to surrounding networks will be very simple, based on paper images or X-ray films. The human printing the paper copies or the analog films (from the PACS) and the laser printer can be seen as a gateway converting the X-rays between analog and digital forms. The point is that in the PACS technology, humans can still print paper copies or X-ray films just as they used to make prints of the analog films in the traditional system. Thus, the gateway enables the radiology department to keep the communication with their analog working customers intact e.g. when paper copies or analog films are printed, the printout can be communicated to the requesting unit, in the same way as it was during the conventional radiological practice, in spite of being a PACS based environment within the radiology department. Hence, the communication between the new PACS-based radiological practice and the conventional medical practice is kept intact.

In the next step, the requesting clinicians will retrieve digital X-ray images from the hospital intranet. This means that the clinicians at the hospital can access all images at a hard-disk level from PACS via an intranet interface, which converts the images to an Internet-readable format on the fly or via plug-ins. In this case, the problems related to sharing X-ray films between radiologists and clinicians will not arise and cause interruptions in work. The interface to surrounding networks will be electronic, based on a hospital intranet browser. Here, the gateway between the two networks is the intranet application converting the PACS images to a format readable from a browser on the hospital intranet.

The third step extends the second one by creating an additional connection, from external requesting units (outside the hospital) to the PACS databases. This uses Internet technology, an alternative similar to the second alternative described. The interface will be an Internet browser, and the gateway will be the application converting the PACS images to a format readable using an Internet browser. If the requesting clinician from the external unit needs analog images, the images may be printed on paper or on films using laser printers. This clinician can work in two separate networks, i.e. the film network and the PACS network. If the request is not printed in the external unit, there will only be one Internet interface, so that all work is based on computers and network technology.

Exploiting the potential of information systems

Many researchers have illustrated the insignificant effects of the implementation and use of PACS within Healthcare (Tellioglu and Wagner 1996, Bryan et al. 1998, Strickland 1998). I believe that the "real" effects may be linked to the insights of opportunities and realizations of new ways of organizing and carrying out the diagnostic work, and new services provided to the radiological customers and patients, based on the digital technology's properties. The "new" work practices rely on a complex interrelationship between the humans and the properties in the new technologies, the work practice and the Healthcare community as a whole. Therefore, in order to explore and make use of the "new" PACS technology and its properties, we need to study the interrelations between medical staff and PACS in various contexts. By studying the links of medical staff and PACS, we as designers and scientists can understand how the technical properties influence the actors" performance. We can also understand the extent to which a technical property really succeeds in achieving a desired action, just as the "real" opportunities of the socio-technical network can be evaluated and considered during a process of change.

It is suggested that the design of PACS could be improved by considering these technologies as *work oriented infrastructures.* This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. Regarding PACS as a work oriented infrastructure as opposed to the universal service infrastructure e.g. railways, highways, power infrastructures etc. has taught us some lessons about the design of electronic radiological infrastructures. We conclude that these infrastructures are, and should be, designed and implemented primarily by their users based on their actual use of the technology. The infrastructure should be built in a piecemeal fashion over a long period – new elements are added to the existing infrastructures and parts are improved or replaced by new ones. The work oriented infrastructures are constructed by linking artifacts together and thereby making them interdependent. A large scale infrastructure emerges as artifacts are linked together and the work of large communities of practice share their meanings. It is suggested that one way to improve and make PACS part of a work oriented infrastructure is to link it to other information technologies in use.

In studying PACS, it was shown that simple electronic lists have the potential to support the management and organization of work in new ways (Paper 1). As a result, new lists were rapidly introduced into the radiological practice to support teaching, interdisciplinary meetings, conferences, teleradiology and medical students. During the study period, improvements and potential new ways of using lists became evident as well. This was demonstrated by e.g. that the information in electronic lists could be used to provide an overview of the entire diagnostic work within the department: who is working where, with what kind of workload, etc. Naturally, this information needs to be provided in new ways. For example, it would be possible to provide an overview of work to the community of radiologists by means of a number of stacks illustrated on the screen, where each stack represents one diagnostic station's "to-do" list. If the workload is high, the stack is high; if the workload is low, the stack is low. If a particular radiologist requests support, a red dot may be displayed inside the stack for the appropriate diagnostic station. Naturally, there should be e-mail and chat functionalities linked to shared "views" (personal communication Ina Wagner and Hilda Tellioglu 1996) as well: one could click on the stack to display a window for e-mail communication. These functionalities could enable the radiologists to support each other in new ways, using a very simple and well-established technology. It would be reorganized and retrieved within a sub-network - diagnostic practice, image production practice, etc. - to support a particular community. The information would be shared through a view of the network available to a particular community. These views emphasize information and functionalities, displayed on the screen, accessible to a group of people that are all related to a particular community: for example, a radiological, clinical, or administrative community. The importance of a shared view is that it enables members of a community of practice to communicate and support each other in new ways. There are no communication functionalities in the existing PACS and RIS, such as email, chat, or Net meetings. Some of the reorganized information and communication functionalities could also be public such as general information about pediatric examinations. Others could be private such as date and time for examination appointments.

An obvious area for shared views is research. For a long time, various medical research areas have expressed their need to access and communicate medical data from RIS and PACS in new ways. Information could be retrieved from the PACS databases through free text search and displayed on the screen among a particular research community. Radiologists could log on to the shared view, access information within a particular field of interest, pool and extract information as well as analyze results, etc. In this way, PACS could contribute to new possibilities for research work.

Different kinds of "to-do" lists relating to various radiological examinations, e.g. skeleton, chest, CT and MR, could be shared and linked through a view within a region, including several hospitals and primary care units. This could enable a radiologist, from his home, to access and diagnose all chest examinations during the night shift in an entire region. Of course, all the radiologists serving an entire region could be provided with the shared view that illustrates which radiologists are on duty where, and their workloads. This could be useful when a radiological unit needs diagnostic support - during nightshifts or during periods when the diagnostic pressure is intense. One can also imagine the new kinds of links that may be established between locally distributed radiologists as these new ways of organizing and communicating work become established.

Naturally, there should be e-mail and chat functionalities linked to the shared view as well. Thus, radiographers may support each other in new ways. The "to-do" lists in laboratories could also be linked to the scheduling lists in the administrative area. This could support automatic updates to laboratory bookings when examinations are canceled. Hence, the facilities in the department may be used in improved ways, just as minimizing delays in patient examinations would improve service to patients.

The shared views based on PACS and RIS information have the potential to become meaningful to the radiological customers and patients as well. For instance, all clinical staff involved in the treatment of a patient could be provided with information about when and where their patients will be discussed: at what interdisciplinary meetings, educational events and conferences etc. through shared views that are automatically created by retrieving information from the different electronic lists. Similarly, one could give the patient information about when and where his/her examination is to be discussed at interdisciplinary meetings, when decisions on treatment will be finalized, what medical staff are involved, hours during which telephone consultations are offered, and e-mail addresses for consulting the medical staff in charge, through an individual view. Patients could also log on to a public view to learn about the examination and the diagnostic unit, or find information on how to contact the radiological unit directly. Introducing and providing aspects such as the ones described here is essential nowadays when the patient's right to improved medical information is generally accepted and even established in law. The gateway between these entities is an application retrieving a cross-section of medical information from the different lists in PACS and providing it via a standardized interface, for instance on an Internet browser, to the radiological customers and patients. Thus, the technology behind these views is very simple and well tried from a technical point of view.

In order to develop new ways of working and new services within Healthcare, new solutions such as the ones described in this section need to be developed around the technology and its use over time, according to the user's needs and interests. This implies that the technology will be used in a wider variety of contexts for many more people and purposes than it is today. The development of new views as new solutions is an example of using borderline resources (as described in section 6.5). Developing these borderline resources is one way to develop the PACS infrastructure. This process takes a long time, as it comprises many interrelated links between the artefacts, the users, social conventions and other elements in the work practice. The process of developing subtle functions of a technology e.g. borderline issues is also a process of making technology domestication. In this process, different medical staff members, patients and radiological customers could use the technology from home, work, a friend's house, school, etc. for different purposes. If these solutions were developed, as suggested above, views could rapidly grow and take on a more central role in the large and complex Healthcare organization.

One way to develop an infrastructure is to develop borderline resources in a process where bits and pieces of technical components are linked to the work practices over time. In this process the application is developed through a series of versions where each version is in use for a period, and the next one is developed based on the experiences with its predecessor (Paper 5). Applying this perspective to the future development of technology use would imply that each new view should be introduced in a number of small steps. For instance, the introduction of stacks representing “to-do” lists for different diagnostic stations should initially be introduced only between two diagnostic stations. The next step would be to link one more diagnostic station to the shared view, adding its workload by means of a stack displayed on the screen in the shared view. After a number of small steps in which all diagnostic stations are linked, a later step would be to let one radiologist who is on duty at night, from his home, diagnose images for one radiology department. A further step would be to add the view from another hospital to the radiologist on duty at night from his home, etc. Designers work in a reiterative design process, based on the links between medical staff, work practices and PACS. The prototype approach has several advantages in the development of computer systems within Healthcare (Paper 5). Applications based on this approach are easy to change as the users’ needs change (ibid.). In this way the application has the potential to grow and meet the challenges of interoperability and collaboration between the radiology department and its customers.

Many steps in the right direction have been made. For instance, the initial technical problems related to PACS have been solved. However, to explore PACS use further, a more thorough understanding of how human actors, technologies and human actors, and various technologies are linked together within the radiological practice is required, since such an understanding explains technologies and their role in work. When analog films were replaced with PACS images, not only technical devices, but also the people, work practices and organizations were integrated. Our results support the findings of Ina Wagner (1994), demonstrating that PACS technology has the potential to create new interrelations between professionals and medical institutions. It is suggested in this section that one way to do this is through the implementation and adoption of views. The application of views means that PACS technology would enhance new meanings in many different settings and contexts for different people based on its social and technical properties. It is a way to accommodate the technology by making it more available to heterogeneous communities of practices.

Summary and Conclusions

Globally, Healthcare is making huge investments in information technology e.g. PACS, RIS and electronic patient records. Implementing such systems in the hospitals has been problematic, the number of systems in regular use is low, and where the systems are in use the benefits gained are far below what has been expected. The overall research question in this study was: How can we improve the design, implementation and use of PACS by studying the complex interrelationships between the medical staff, the technologies, the work practice and the Healthcare community as a whole?

This study started out by exploring and illustrating the impact of PACS on radiological work (paper 1). It was concluded that the introduction of PACS is not just a matter of technology transformation – people, work practices and organizations are transformed as well. Analog films are not simply replaced with electronic images. The work practice associated with film handling is replaced by a new and different work practice related to PACS. It was also concluded that the activities and the sequence in which they were performed remained unchanged, while the performance of most of these activities changed. Finally, it was concluded that PACS technology changes the radiologist's role in work. For example, the radiologists became their own assistants, secretaries and archive personnel.

It was also illustrated that artefacts in radiological work are highly interdependent (paper 2, 3 and 4). The shelves, binders, folders, tables, mailboxes, typewriters, tape-recorders etc. are all linked to the radiological paper request form. In addition, these artefacts are linked together into long chains. The chain of artefacts is also linked together with the working practices of the personnel, i.e. the radiologists, radiographers, clinicians, secretaries and administrative staff as well as the transporters. Furthermore, the various medical work practices are linked because clinical departments need to communicate with all service departments. Together this means that the work practices at hospitals are linked together into large socio-technical networks.

The fact that the radiological paper request form is one single physical object plays a crucial role. It was illustrated in this study that by considering artefacts' central, peripheral and shared properties, it is possible to achieve an understanding of how artefacts are embedded in work. These artefacts are of great importance for overview, awareness, coordination and trigger of work (paper 3). Thereby, we get an idea of the essential resources and prerequisites for the work being done. This helps us to understand what resources the new information technology initially should replace in a translation, even if there is no guarantee that it will be used in the way expected. However, over time, the new technology must be integrated in work according to its own properties and potential and not according to the analog technologies.

Infrastructures and work practices change over time (paper 4 and 5). Due to their size and complexity, they cannot be changed instantly. Hence, infrastructures and working practices co-evolve slowly over long time, through a series of small steps. It was also concluded that the more resources linked to the analog infrastructure the greater the probability of resistance to transformations. In addition, it concluded that the larger the medical network implementing PACS the harder it will be to coordinate the actions of all actors in a change.

It was found that computer systems based on different electronic standards intervene in work in different ways, and that they do not always intervene the ways they were initially intended (paper 5). For example, the PACS based on the DICOM standard have primarily attained a local role, although its initial aim was to support universal image communication within Healthcare. On the other hand the intranet application based on the Internet standards primarily not designed for this particular purpose has come to support communication of images and reports within the heterogeneous hospital network.

It is suggested that the design of PACS and RIS could be improved by considering these systems as *work oriented infrastructures* (paper 4). This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. PACS and RIS, as work oriented infrastructures, have taught us some lessons about the design of electronic radiological infrastructures. We conclude that these infrastructures should be designed and implemented primarily by their users, based on their actual use of the technology. The work oriented infrastructures are constructed by linking artefacts together, thereby making them interdependent. It is suggested that one way to improve and make PACS part of a work oriented infrastructure is to link it to other information technologies in use. For example, medical researchers have expressed a wish to retrieve tailored research data concerning various diseases, this could be achieved by automatically retrieving segments of medical data from PACS, RIS and HIS and presenting these through a third technology, for instance the internet. Shared conventions and rules, e.g. the fact that the paper request form must be placed on a particular place at a table in order to communicate to the radiologist that there is a patient to be diagnosed, are of significant importance for the conduct of medical work. It is of great importance to develop shared conventions and rules related to the use of work oriented infrastructures. In the linking of computer systems segments, of adequate information can be retrieved from one or several systems, presented as a common view for several users i.e. shared view. Introducing views is a way to accommodate the technology, and at the same time making it available to heterogeneous communities in different contexts.

Designing and implementing computer systems such as PACS cannot be performed in a “big bang” process. The actor network can only be changed in a process where smaller parts are replaced by new ones bit-by-bit. The old and the new socio-technical networks must be linked through interfaces, enabling networks with different technical solutions to communicate and interact.

To summarize, firstly, to improve the application of PACS and RIS in medical practice, the design of computer systems has to be informed by a better understanding of all the roles and meanings of the x-ray films and paper request forms in work. Secondly, there is a great potential for improvements in performance of these systems through relatively simple means, by implementing the achieved knowledge in the medical actor network.

Future Research

Future research on PACS and RIS should focus on how we, as designers, can improve the use of these technologies within Healthcare. A natural follow-up of the studies conducted for this thesis could cover three aspects. Firstly, what borderline resources, for instance individual, shared and public views, could be developed where and for whom? Secondly, how can we design and implement the gateways behind the various views based on internet technology within Healthcare? Thirdly, what can the implementation and application of different views within Healthcare achieve? Will this, lead to new ways of organizing and communicating work and/or will it provide new services to the radiology department's customers or patients?

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Paper One

Impacts of PACS on Radiological Work

Nina Lundberg

Abstract

This paper identifies and analyzes the impacts on work practices and interdependencies in radiological work by Picture Archive and Communication Systems (PACS). It illustrates that when PACS was introduced not only technical devices were integrated, but the people, work practices and organizations as well. In addition, the paper illustrates how detailed workplace studies may identify substantial social changes, emerged from initially insignificant technical solutions that rapidly grows and quickly becomes embedded and central in large and complex networks as Healthcare.

Keywords: Technology impact, work practice, artefact, PACS, Healthcare.

1. Introduction

In complex and durable organizations such as Healthcare the needs of sharing vital information within the departments as well as with other medical units are obvious. This is one of the main reasons why PACS[8] is increasingly being introduced in the medical field at considerable costs. At the time being, 60 % of the radiology departments in Sweden are in the process of or planning to introduce PACS by year 2002 [16]. However, there exists little knowledge of the consequences of heterogeneous socio-technical networks using information technology, such as PACS in Healthcare [21].

Artefacts and humans can be viewed as entities linked together in a socio-technical web, of both humans and artefacts. To improve the understanding of people and things in radiological work practice I will use the Actor Network Theory's notion of inscription (see e.g., Callon [6], Latour [15], Akrich [1] and Law [17]). Inscriptions can be properties, i.e., features, characteristics, and possibilities inscribed in artefacts as well as meetings, institutional arrangements, skills, etc.

This paper illustrates that PACS images obtain new properties, compared to film-images, that impacts the work practices and interdependencies in work in

[8] PACS supports the electronic storage, retrieval, distribution, communication, display, and processing of x-ray image data.

different ways. In this work three important aspects of PACS images that differ from film images are highlighted:

- They are established in spaces e.g. are electronic and not physical.
- They have indefinite manipulative forms e.g. any type of functionality may be programmed and linked to them.
- They have an indefinite geographic scope e.g. may be linked to any distant electronic network.

These three aspects shape the way PACS images are used and to what and whom they are linked. Just as the fact that film images are dark, tangible[9] and physical originals also shape the way they are used and to what and whom they are linked in work. The properties of PACS and film images set particular prerequisites for radiological work. However, these properties may be interpreted by its users in manifold ways [15]. Therefore, the way properties are made use of may not necessarily correspond with the intentions of the designer.

In the present study the impacts of PACS technology are based on detailed work place studies at radiology institutions in Sweden. The study can be characterized as "Quick-and-dirty Ethnography" [2; 3; 4; 5; 13]. This research method has lately become widely recognized within the IS field. The research approach emphases on investigation and understanding the actual work practice in context. The empirical fieldwork was initiated in October 1996, at the Pediatric Radiology Department, Sahlgrenska University Hospital/East, Sweden, (SUO)[10]. This is a conventional, non-PACS, radiology department. In addition, two episodes of data collection relating to the operations with PACS departments at the Thoracic section, Radiology Department, Sahlgrenska University Hospital, Sweden 1997 (SU), and at the Pediatric Radiology Department, Astrid Lindgren's Children Hospital, Sweden (ALB), in March 1999 are included.

The studies of the digitized departments took place one year after the PACS implementation, indicating that there had been sufficient time to adapt to the use of PACS. Several different techniques were used: workplace video studies; interviews articulated by the illustration of video documentation; unstructured interviews; observations and an integration of discussions-interviews and observations of diagnostic practice and social interaction. In total, more than 40 hours of video documentation were conducted, about 60 hours of radiological work were observed and 25 interviews were conducted. The interviews were conducted with mainly radiologists but also radiographers, secretaries, technicians, assistants and computer retailers, each about an hour and a half in length, with some participants being interviewed more than once over the period of study.

The ethnographic methodology was chosen for its ability to achieve "the practitioners point of view" which in this case is mainly the point of view of the radiologists. Suchman [23, 24] has also pointed out that the importance of

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9 Refers to the fact that films can be brought to many different contexts in which they fulfill. some aim and purpose.

10 After this study was conducted has the hospital been renamed: " The Queen Silva Children's Hospital".

making work visible for systems design is to develop more appropriate technologies from the point of view of those who will be using them. In addition, previous systems design research has illustrated that deficiency in the understanding of work practice often contributes to computer system failure [8; 14].

It was found that the availability of images offers possibilities for parallel work activities and diagnosing of images to be carried out from practically any connected place at any time. New activities have been designed operating with PACS, e.g. the creation and use of various electronic lists. It has been illustrated that these lists offer new ways to organize, share, present and communicate radiological information. In addition, it also offered medical staff new ways to support each other, just as it contributed with efficiency effects in work e.g. reducing the time required for the presentation of interdisciplinary meetings. As different medical units are linked to PACS, they all become part of a socio-technical actor network. Furthermore, it was found that PACS technology has led to the decentralization of interdisciplinary meetings to the clinical units, in which a radiologist visits a particular clinical unit for a meeting, instead of having clinicians from different wards simultaneously visiting the radiology department. Unfortunately, designers have lacked understanding of the role of meetings as an essential forum for discussions between clinicians from various medical units as well. When these meetings are decentralized an important recourse in medical work has disappeared e.g. the clinicians interdisciplinary meetings, challenging the stability in work.

The aim of this paper is to analyze and illustrate PACS impacts on work practices and interdependencies in radiological work, and more specifically to, focus on how initially insignificant technical solutions rapidly grow and thereby change peoples understanding of work.

The remainder of the paper is organized as follows. In the second section radiological work is described. The third discusses PACS impacts on radiological. The next section presents challenges for design, and finally are the conclusions presented.

2. Radiological Work

The radiology department is a service unit, carrying out radiological examinations and procedures for clinical departments inside the hospital, other hospitals and primary care units (general practitioners). Radiological images are an important tool establishing the diagnosis of patients in the hospital wards and out-patient departments. The radiology department supplies interpretations of radiological images and the results are ”delivered” to clinicians by means of reports and meetings. The radiological examinations and reports form a basis for the correct diagnosis and treatment of patients within Healthcare.

The examinations offered to clinicians by the radiology departments are usually grouped in relation to the body’s organ system, such as, skeleton, chest, mammography, odontological, gastrointestinal, genitourinary and vascular examinations or related to type of equipment used: ultrasound, CT (computer tomography) and MRI (magnetic resonance imaging).

PACS technology is an image archiving and communication system. Its main function is to create a shared electronic space where radiological images can be saved. PACS facilitate the sharing of the image data across organizational and professional boundaries. Images can be archived and organized in central units, and be accessed and used cooperatively by locally distributed actors. In combination with hospital information systems (HIS) and radiological information systems (RIS) PACS allows the management of work associated with radiological examinations in a hospital. RIS are mainly used for administrative purposes, including functions for: communicating and managing patient data and examination requests sent from HIS, managing patient registration, scheduling radiological examinations, creating reports used for accounting and producing radiological reports.

2.1 Introducing PACS at Sahlgrenska University Hospital

In 1995, a proposal for the installation of PACS at the Thoracic Section, Radiology Department, SU was forwarded. This move was in conjunction with a move of the radiology department to a new location. The new radiology department was built and equipped by May 1996.

PACS technology is built around a central archive to which all workstations are connected through fiber distributed data interface (ATM)/fiber optic network. PACS support the electronic storage, retrieval, distribution, communication, display, and processing of image data. After the PACS had been in use for a while, both clinicians and radiologists wanted to extend the system with functions enabling the clinicians to access the images from PC’s at the clinical departments. As the PACS technology was running on Unix work stations, the software could not just be installed on the PC’s. Instead an application was tailored to convert the images “on the fly” to a format readable from the hospital Intranet. This was a simple solution developed by a master student within a three-month time span. This means that the clinicians within the hospital can access all images at hard disc level from PACS, at any time from any PC connected to the Intranet, without an explicit request from radiologists.

A similar implementation was made in May 1998 at the Pediatric Radiology Department, Astrid Lindgren’s Children Hospital. However, there are a few differences in the design process and structure of these two PACS solutions. This is not an in-house tailored system, it is a system bought from a retailer. This means that the radiological department with its staff has not been involved in the design of this system. Another difference is that plug-ins to web browsers have been developed converting both the documents in RIS and images in PACS to a format readable from the Hospital Intranet.

2.1.1 Radiological work practice

All activities within the radiological practice are linked together to make the overall patient examination and diagnosis smooth and efficient. Therefore, in order to understand the radiologist's activities, we also need to understand the activities linked to the radiologist's activities, such as examination request creation, scheduling, image production and distribution, clinical image demonstration and patient treatment. Although this study concerns different radiology departments, it is possible to compare how work practice has been shaped by the use of PACS images, since the work practice is quite standardized at Swedish hospitals and the results thus may be valid for Swedish hospitals as a whole.

In the next section the radiological practice as well as other clinical activities linked to it in conventional working and radiology departments operating with PACS will be described.

2.1.2 Conventional work practice at Sahlgrenska University Hospital East

For a radiological examination, patients are usually sent from clinical wards, outpatient clinics, primary care units etc. to the radiology department. At SUO an examination request is created manually by a paper-based system. It includes data such as the patient name, date of birth, the name of the clinician requesting the examination, the type of examination required (e.g. CT, MRI, angiography, chest examination, ultrasound, mammography) and the patient's symptoms and the clinicians preliminary diagnosis. When the examination request is received in the radiology department, it is scheduled by assigning an examination room and a radiographer or a radiologist to the examination. If there are any prior examinations that seem relevant, images are requested from the archive. The file room is located two floors underneath the radiology department. A system is used whereby the shelves are numbered with date of birth of patients. In addition, the envelopes have striped stickers to indicate the modality by which the examination was undertaken. In extreme cases one and the same patient may have undertaken more than one hundred examinations. It is expected that the file room staff finds old films before a new radiological examination is carried out. A list of all patients booked for examination is sent to the file room a week before examination day. In addition, they often receive phone calls from radiologists requesting them to find additional films to facilitate evaluation of a current examination. The films are transported in trolleys in between the file room and radiology department. In practice, unfortunately, some clinicians or radiologists may hold on to some films after patient diagnosis, bringing these film images out of the archiving system, causing interruption in routine work.

The day before the examination is taking place the request form is placed in a trolley. It is organized according to examination type and scheduled time. A glance in the trolley gives an overview of the day's schedule. The radiographer collects the examination request form from the trolley. The patient is brought into the examination room and positioned for the examination. The radiographer loads a cassette into the image production machine and exposes the film, which is held in a cassette cover. The cassette is fetched and placed in a film-processing machine, and the developed films are positioned on a light board for quality evaluation. If the previous films are unavailable, the new films may be taken down and placed in a pile awaiting old films.

In the department, there are usually four to five radiologists being assigned to interpret film-images every day. The radiologists are working side by side, with light boards linked together in a row in the diagnostic area. A radiologist commented that she would have liked to have the possibility to turn off the lights in the squares on the light board, except for the square she is working with. She continued: ”It is harder to concentrate on each individual film, because I am watching against the light, which is very constraining for the eyes”. In the same area medical assistants are positioning new film-images and taking down already reported films from light boards, secretaries and confronting radiologists with transcribed reports to be signed off and radiographers are checking film quality. The radiologist is carrying out work his/her by moving around in this room, a glance at the pile of requests at a table gives an overview of the urgency and volume of work. The radiologist collects the paper requests, walks back and while standing, he starts to read the date and clinical request at the top of the paper request form. He then scans the prior reports related to old examinations of the patient, skipping the middle parts that are related to the radiographers work. Based on this information, he decides in which order the films need to be read. The films are then positioned on a light board. Sometimes, the radiologist realizes that additional old films are needed. If so, a secretary is requested to fetch these film-images from the file room. In these cases, the request is placed in a “wait” pile until all old images are mounted on a light board to be compared with the new film-images. The search for film images is connected to winding trajectories, as medical staff expressed it. To fetch and position old films may count anything from 15 minutes to half a day depending upon the urgency of the case. The radiologist reads and compares the images, which may be anything between 2 and 150 images, placed on one or several light boards. To read the images he compares the contours, shapes and densities in the image. The evaluation may include the use of measuring devices to assess distances, angles or densities of the findings.

Fig. 1. Radiologists reading film images.

When the evaluation is made the radiologist dictates the report on a tape. The secretary transcribes the report. The report document is now visible for the radiologist, he walks over and collects the document, reads it and signs it off. A staff member fetches the signed reports and places them in an out-shelf for respective requesting department. The reports are picked up in the out-shelves by transporters and brought to the ordering departments. In about 10 % of the examinations do clinicians request the films to be attached to the radiological report. In these cases the films are taken from the radiology department and sent to the requesting clinical unit. In addition, a patient may become severely ill during the night. In these cases the film-images must be fetched. When this happens a paper sticker is placed in the area from which the films are taken.

There are nine daily interdisciplinary meetings called “radiology-rounds”, and five weekly multidisciplinary conferences. During these meetings the radiologist, with the request forms at hand, gives his evaluation of the examinations. The cases are briefly described, and the clinicians may discuss further diagnostic possibilities and the treatment of the patient. The films come in different sizes, equivalent to the size of the organ it represents. For CT a video camera is used to zoom the images on a TV monitor, because the original is too small to see for the audience. This means that the radiologist leading this round is more or less moving around during the entire presentation, pointing at different findings, placing the video camera while explaining. All images must have been prefetched from the file room prior to the round, there is no time to obtain additional old films during the round. These meetings update information on the condition of the patient. In addition, they are *the* interdisciplinary forums for discussions of patient’s future examinations and treatment within the hospital. Hence, these meetings are not just detailed statements of radiological findings, they are also the events where interdisciplinary diagnosis and treatments of patients are discussed.

Fig. 2. Meeting at the Radiology Department.

At several occasions each day, clinicians call and visit radiologists, to get answers to questions they have about their patients as well as choice of examinations. Such ad hoc meetings are needed whenever there are emergency cases or severe complications in the progress of a patient’s illness. In these cases, the radiologist usually asks a secretary to bring forward the patient’s medical record and film-images. This may take anything from five minutes to half a day, depending upon the location of images and reports and upon the urgency of the case. Many times the clinicians are asked to visit the radiology department, for a face to face discussion, in which the radiologist has a chance to illustrate the film-images to the clinician.

2.1.3 PACS based work practice Sahlgrenska University Hospital

The paper request creation at the clinical units, its distribution to the radiology department as well as its scheduling at the radiology department is carried out in the same way as before. If the patient has been examined before 1996, the secretary must request these images from the film archive. When the patient is being scheduled a message automatically is transferred from RIS to PACS. This message triggers the automatic pre-fetching of relevant examinations from the long-term PACS archive after midnight the night before patient examination. Retrieval time is kept to a minimum by the fact that the fetching of the next day’s images takes place in the slack hours the night before, and thus do not compete with any new images being archived. The retrieved images are available from the information storage unit, and can be viewed on the screen within a half to five seconds after the radiologist has ”clicked” on them. Images that are not automatically retrieved must be retrieved from the permanent long-term archives usually in three to ten minutes, but the procedure may take longer if the system is busy. The instruments generating the images are nowadays all based on digital technology. This means that when the radiographers are producing the images, they are directly stored in the database of the PACS.

The day before the examination is taking place the paper request form is placed in a shelf visible to the radiographers. The radiographer collects the written request and walks to the laboratory. She uses a hand scanner to scan the bar code, which is attached to the paper request. The patient’s electronic data is thereby retrieved on the workstation. She then positions the patient and performs the examination. The radiographer views and selects the PACS images, adjusts the density level to produce the optimum image, performs any reorientation and annotation which is necessary, and then verifies the examination. When the images have been verified PACS automatically transfers the images to a folder, containing about 1500 examinations for reporting. The paper request is then manually distributed to the diagnostic area, where it is placed in a shelf visible for the radiologists. The radiologists can see how big the piles of requests in the shelves are while walking around in the image interpretation area. When it has reached a certain size – which depends on the degree of urgency of other tasks – the radiologist fetches the pile from a shelf and sits down at one of the PACS workstations. All workstations are provided with infrared barcode readers. The radiologist fetches patient data on to workstations by ”sweeping through” a barcode-encoded ID sticker attached to the paper request. When all barcodes have been swept through a “working-list” has been made. With paper at hand he clicks on the first patient in the working-list. He reads the patient name and ID in the written request and checks it with the patient data in the electronic request.

Fig. 3 Radiologist reading images.

Three monitors are situated side-by-side. In the far-left one, PACS and RIS are integrated into one interface, while the middle screen illustrates the new images and the right illustrates the old images. When the radiologist shifts between various new chest images will the corresponding old image be automatically displayed on the right screen. The radiologist zooms and uses the tools to magnify and change the contrast of images. Manipulation of the images on the workstations allows a range of densities to be seen in the image, just as it allows the instant measurement of various findings. Images are compared through the shift between images showing different views of the patient's chest. He looks again at the electronic request and realizes that there are some X-ray films from an earlier examination. He fetches the films from a trolley and positions them in a row at the light board located adjacent to the computer screen. The radiologist reads and compares the images on screens and light boards to complete the diagnosis. After the diagnoses have been made the radiologist must decide whether the examination should be brought up on the radiology-round or not. If so, he must drag and drop the electronic request to the relevant "meeting list", and place the written request in a particular pile at a table. The radiologist's reports, when short, are entered directly into the RIS by the radiologists themselves. He prints the report on a laser printer and puts it into a plastic folder together with the paper request and places it on a shelf. In case of a long report the radiologists dictate their reports on tape. Typists transcribe the reports on RIS, print it on paper and place it on the radiologist's shelf to be signed off.

Fig. 4. Meeting at the Radiology Department.

At the daily meetings at the radiology department, where radiologists and clinicians discuss the examination, the request forms are placed in a pile at a table and electronic images are fetched from the “meeting-list” in PACS. During the meeting images are shown on a “movie-screen” (1,5x3 meters) and film images are positioned on an adjacent light board. The radiologist is facing the audience through the entire meeting. The images are illustrated two at a time, side by side. He zooms and filters the images to highlight contrasts in findings. The conference folder has to be “prepared” before the meeting by selecting relevant images within each examination for review at the meeting, and the rejection of all images which were not required.

The PACS and RIS systems are essential during the ad hoc discussions between radiologists and clinicians. To access patient reports and images the radiologist enters the patient ID numbers into the RIS. RIS respond by displaying a list of all previous examination, which the radiologist can chose among. Often during these discussions, the clinician wants to have the opinion from the radiologist whether an abnormality has changed over time. In such a discussion, instant comparison of images is crucial.

In spite of the training and the more activities added on the PACS users, the majority of staff considers the systems to be both easy and preferable to use.

2.1.4 PACS based work practice Astrid Lindgren’s Children Hospital (ALB)

The work practices at SU and ALB are very similar. There are, however, a few differences. Firstly, at ALB an examination request is created on HIS and printed on paper. The paper request is hereafter scanned into the RIS at the radiology department. This enables the radiological staff to access all medical data of the patient via RIS and PACS.

Secondly, the room used for the interdisciplinary meetings at ALB is simultaneously used as a diagnostic area, with four PACS workstations located in the opposite end of the room. Finally, not all meetings are nowadays given in the meeting room at ALB. For practical reasons, some rounds are carried out at the clinical departments. The trend is to “locate” the meetings to the respective functional clinical unit. For instance, the clinico-radiological meetings with medical staff from the surgery and the oncology departments at ALB have been translated from the radiology department to respective clinical unit. In addition, may occasionally, the entire room may be used for meetings at ALB.

3. PACS Impacts on Radiological Work

The picture archiving and communication system at Sahlgrenska University Hospital was developed in an improvisation [19] like process, i.e. through a series of versions where each version was in use for a period, and the next one was developed based on the experiences. Through such a process, a system well adapted to users' needs was developed. The efficiency in work is a central goal for introducing PACS. From this perspective, the aim is to become a completely filmless hospital, in which the acquisition, storage, distribution, reporting and viewing of all images would all be in a digital computerized form using a hospital-wide network of viewing stations.

The transformation from film images to PACS images is a challenge. Because, the more resources linked to the film images the greater the probability of resistance to translations. In Healthcare numerous artefacts have over a long time been linked to each other in the socio-technical network. For example, artefacts surrounding the film image are light boards, cassettes, film production machines, shelves, tables, printers, dictaphones, archives, telephones etc. Work practices have been shaped according to all these artefacts, as well as the spaces arranged around these artefacts. Other recourses have also been invested in: knowledge and skills surrounding the films, file room staff, secretaries, medical assistance etc. Transforming film images to PACS images means that the new artefact's properties do not fit into the old artefact's links. Just like the paper medical record's links e.g. shelves, typewriters, binders etc. do not fit into the new electronic document's links[11]. This implies that the existing structure may constrain the new one [19].

The two next subsections discuss and analyze artefacts in work practice to gain a better understanding of the impact on radiological work. When x-ray films become electronic they lose and gain properties that seem to be important in work practice. How the new properties become important has to be taken into account in order to understand the use of artefacts in Healthcare.

3.1 Impacts on Work Practices

PACS images obtain new properties that will impact the work practices in different ways. We will in this subsection describe how artefacts with different properties impact work practices.

Working with PACS images, being electronic and not physical, not only enabled clinicians constant availability of images, but also enabled the images to be viewed by any number of people from any PC display in the hospital, this was a benefit. With PACS, in theory, the radiologist is able to instantly locate and view the image(s) in question on any workstation connected to the hospital network. The ease with which images could be distributed via PACS was very important, because it affected the users' productivity, and also - more importantly it affected the users' acceptance of PACS. The shared information is accessed for different purposes at the different places simultaneously, images can be discussed over the phone, diagnosed on a work station, demonstrated on a round etc. This implies that clinicians could view the newly exposed images while discussing the patient with a radiologist over the phone. This has positive

[11] For more readings of paper's meanings and roles in practice, see [11, 12, 13].

impact for medical staff, since they spend less time being involved in film searching activities.

In the conventionally working radiology department it was hard to concentrate on each individual film image, because the light boards were constraining for the eyes. In addition, film images, from one and the same patient, could be positioned on several boards, requiring the radiologist to move around while reading images. Furthermore, the diagnostic area was a quite “crowded” place, where radiologists read film images, radiographers checked film quality, assistants positioned films and secretaries confronted radiologists with transcribed reports. These phenomena are all in contrast with the PACS based practice. When operating PACS only one picture is illuminated at a time on each monitor. The reading room is only occupied by a couple of radiologists (see figure 3). The digital system allows instant measurement and a new range of densities to be seen in the image. In addition, it puts more demands on the radiologists, requiring them to initiate and/or perform more activities related to radiological reports. They may, for instance, call and order previous film (i.e. non-digital) from the archive, in case there are any, and position these films on lightboards by the workstations. They must also retrieve older PACS images onto the PACS monitor. This can be done automatically by appropriate algorithms implemented in the computer applications. If off-line images are needed, the radiologist must send a request to the personnel in the (central) archive to put the correct optical disc into the jukebox. Furthermore, they must retrieve the latest report of the patient, if there is one, from the RIS. Finally, the radiologist reads and compares the images to complete the diagnosis, and if the report is short, the report is entered into RIS directly by the radiologists. In the old technology the radiologist dictated the diagnostic report on a dictaphone. A secretary later transcribed the tape. In a RIS- and PACS- based radiology department, the radiologist could write the answer directly into the RIS and print it on a laser printer located by the workstations. This is of course a much faster way of getting the result on paper since it involves fewer people to get the job done. But from the radiologist’s point of view writing answers is a less sophisticated kind of work which “steals” important time from other activities.

The simultaneous use of two technologies (film and PACS technology) requires the medical staff to cope with and manage two technologies concurrently. This means that the radiologists are linked to two networks when interpreting images (also in meetings) – one based on digital images, the other on film images. The more technical and advanced piece of equipment, the higher the level of skill is required to understand and use it. PACS require computer training to be used; to bring the image up on the screen, but also the ability to read and manipulate it appropriately and accurately.

In the conventional working radiology department the medical staff is working with film images supported by administrative staff. However, when operating with PACS and RIS these tasks are now instead supported by a HIS - PACS interface. For instance, to trigger prefetch of historical images from the long term archive when a patient is admitted to the hospital; to track patient location so that PACS worklists (e.g. of which patients are currently in which ward) are kept up to date; to inform PACS when patients are discharged form the hospital, and their images are no longer required on Short Term Storage.

Using PACS, the time required for the daily meetings has decreased with 30%, according to the chief radiologist.

This paper suggests that when analog films were replaced with PACS images the achievements in work were insignificant. The traditional sequence of activities to carry out work remained unchanged, i.e. although films were produced in another way, the steps in the radiological work, starting with the patient registration, continuing with patient examination and finally evaluation and diagnosing of films/images remained unchanged. However, the performance of most of these activities, as illustrated in the examples in this section is changed i.e. substantial changes in work were identified on a detailed activity-level.

3.2 Impacts on the interdependencies of work

According to actor network theory, changes in artefacts' inscriptions impact the network they belong to. PACS images have properties different from film images, as we described in the previous subsection, and substituting film images has consequences for the work process they are part of. We will in this subsection describe how these properties impact the interdependencies in work.

The radiologist's role has been transformed in order to fulfill some aims and intentions. Working with PACS, the radiologist initiates and completes most activities related to diagnostic work, without being interrupted or serviced by another ”community of practice”. Work is not as a standard procedure handed over to secretaries or radiographers for additional information, print outs, positioning films etc. Radiologists have an increased responsibility to keep the entire trajectory of diagnostic work moving. The radiologists are now their own assistance's, secretaries, archive personnel, etc. It is not just that they have to do what other ”communities of practice” had to do before, but the introduction of PACS also brings on new activities, for instance, creation of “working-lists”, “meeting-lists”, “teaching-lists” and manipulation of image data.

In the conventionally working radiology department, the secretary and radiographer prepared and positioned the images for the interdisciplinary meeting after the filing clerk had already spent time locating as many examinations on the list as she could find. When operating with PACS the examinations were already placed into a “meeting-list” by the radiologist who had read the images. Radiologists are less dependent on administrative staff in work.

Before the PACS-system was introduced, the radiologists had to coordinate nurses and secretaries to make a phone-call to the central archive to access images. Sometimes, someone else used the requested images, the trajectory of that patient was then placed in a “wait” pile, causing interruption in work. Today, by using PACS, the images are immediately accessible for all clinicians at the hospital, even before the radiologist has diagnosed them. The shared information may be discussed over the phone while simultaneously demonstrated on a multidisciplinary meeting. This illustrates that the radiologist has become less dependent of secretaries, clerical staff and assistants in work.

In order to maintain the adequate technical performance of PACS and RIS a team of technical staff is required to work at the hospital. The radiologists are dependent on this new category of staff to support them with technology that functions in practice. The medical staff needs to be teached and serviced by the technical staff. The radiologist has become more dependent on these technicians in their diagnostic activities.

The relation of dependencies between communities of practice was very clear in the old network where ”a doctor was a doctor and a nurse a nurse”. This has become less clear in the PACS network, where a radiologist can position films and write reports. Although the radiologists were of the opinion that the working environment was better with PACS and they sensed work was more efficient, some radiologists commented, saying that the service was better in the old days. They meant that it was a waste of resources if a radiologist had to do administrative instead of diagnostics work for which he or she was specially trained.

After the PACS technology has been in use for a while, both clinicians and radiologists wanted to extend the technological scope to enable the clinicians to access the images from PC's at the clinical departments. As the PACS technology was running on Unix work stations, the software could not just be installed on the PC's. Instead a gateway by means of an application was tailored and "on the fly" converting the images to a format readable from the hospital Intranet. A gateway by means of plug-ins to web browsers was developed at ALB, converting the images to a format readable by Web browsers. These gateways enable the clinicians to access the images via the hospital's Intranet even before the radiologist has diagnosed them. Outside the radiology department, this gateway was considered beneficial. For instance, in the Intensive Care Unit, the time from examination to image availability was shortened. In orthopedics, the use of PACS was found to be associated with a small but significant reduction in the consultation time in the fracture clinic [21]. Healthcare staff in general, regardless of being a clinician or radiologist needs to be kept informed of the status and results of activities related to his own. There is a need for an established flow of medical information from the clinician to the radiologist. Through the introduction of this gateway, all clinicians become parts of a large information system. It was not only the technical devices that were integrated, but the people, work practices and organizations as well. The interconnectivity between the clinical units (within the hospitals) and the radiological unit became more intense operating with PACS.

In the conventionally working radiology department all meetings were given in a conference room at the radiology department, equipped with a long row of light boards. There was no availability of additional film images during these meetings. Operating with PACS, allows the availability of all images from any workstation or PC that is linked to the Intranet. As a consequence, more and more meetings are now instead carried out on workstations at the clinical units. For instance, the joint clinico-radiological meetings with medical staff from the surgery and the orthopedics departments at ALB have been relocated from the radiology department to the surgery and orthopedic departments, respectively. This relocation of meetings to different clinical units has consequences for the interdependence between different clinicians. It may have drawbacks for the cooperation between different clinicians due to the disappearance of joint meetings. Relocation of meetings to the clinical units also influence the coordination of work in the radiology department. As radiological diagnosis often requires comparison with previous examinations, old examinations need to be available. As the digital image system was implemented only recently, old examinations often means analog films, that need to be transported from the radiology department and back. This means that these films are not available for educational or second opinion purposes at the radiology department. It also had an impact for the interdependence between radiologists and clinicians, since the instant availability to images allowed improvisation in work during the meetings. The radiologist can now respond to clinicians ad hoc requests of image display during the meetings.

PACS technological scope has consequences for the interdependence between different radiologists as well. PACS supports the co-diagnosing of images between radiologists in different places (hospitals). In all, PACS have evidently transformed the interdependencies between many communities of practices in Healthcare.

The next section analyzes what it means to carry out radiological work on the screen.

4. Changing the Understanding of Work

The new functionalities are related to newly designed activities. The most obvious ones are the new processing possibilities of PACS image data. Other activities not as obvious, although very important for work, are the ones surrounding the creation and use of "lists". A list is an ordered selection of patient names and IDs in a column. It is made by "swiping through" barcode-encoded ID stickers attached to the paper request with a hand scanner. The radiologist clicks on a patient in the list to retrieve the patient's new and old images as well as previous radiological reports.

The first obvious list invented at the radiology department was the "working-list". This list is used to support the organization and management of diagnostic work. The initial idea of a "list" was to be able to collect and separate the images that are needed to be diagnosed with the other images in some way. The patients in the lists are sequentially ordered according to diagnostic priority. The first patient to diagnose is on top of the list. It becomes a "to-do list" in the reading of patient images. The radiologists were initially against the idea that they were to create these lists. They thought of it as administrative work that could just as well be carried out by administrative staff. Their idea was that it was better to use their time on clinical work.

Rapidly it was realized that there was a need for more lists in work. Radiologists recognized that after finalizing the diagnosis of a patient from a "working-lists" could they drag and drop this patient to another list, for instance a "meeting-list". This barely added any extra work for the radiologist, while it simultaneously reduced the time needed for the preparation of interdisciplinary meetings. The meeting-lists contained all patients to be discussed during the next interdisciplinary meetings. Patients could be added to one and the same list from various working-stations. The lists were in this sense shared among various radiologists diagnosing patients. The radiologist in charge of the interdisciplinary meeting, who was to present and comment images during the meeting, had in this way been supported in work by his colleges. The radiologist only had to go through an already created meeting-list, and maybe make some rearrangements, instead of creating the entire list by himself. The meeting-lists enabled new ways to prepare for and present patient findings on, this is of course essential for the way the entire meeting is carried out. Using PACS the time required for the daily meetings has decreased with 30%.

In addition, the radiologists also created "clinical-lists", for instance, "orthopedic-list". These lists may be seen as a new service offered to the clinical departments. Enabling the orthopedist to access each radiological image much faster, within 2-5 seconds instead of 2-5 minutes. One and the same patient was often dragged and dropped in several lists.

Another, rapidly invented list was the "teaching-lists". There is a teaching session every day at the radiology department. All radiologists contribute to the "teaching-list". More junior radiologists contribute with cases that they find difficult to read and diagnose, while senior radiologists tend to add "interesting" cases. During the teaching sessions, patients are discussed according to the order of the list. When a patient is brought up on the screen, the radiologist that has added this patient to the list explains why it is added, an open discussion breaks out, usually to be concluded by one of the senior radiologists. As the "teaching" list is worked through, discussions also cover if individual cases should be added to other lists, for instance, "seminar" lists and/or "conference" lists. If so, the patient is dragged and dropped in the respective list. At the end of the session, it was an open discussion of whom among the radiologists that could present this particular "seminar" list on a meeting coming up. Since, all radiologists have both been involved creating the list as well as discussing the lists, could this be just any of them.

In addition, there are a number of individual and public "research" lists, used in research work within Healthcare. These lists are created in the same way as the other lists. Although, usually used more individually.

These lists support the organization and management of work. They become "to-do lists" in various settings (as shown above), and have rapidly become essential for work, in a way that keeps the work practice together. The radiologists design and use these lists not only to organize their own work, but also to share work with others e.g. a list may be passed on to someone else. These lists have also opened up new possibilities to communicate in work and support others in their work, just as they also support an overview of work. For example, a glance at, a working-list makes the radiologist aware of the number of patients to be diagnosed.

As I have seen radiologists rapidly invent new kinds of lists, that quickly becomes an embedded part of work. List-making opens up for coordination of work that is distributed widely over time and space. Lists have been shown to be most important for large-scale coordination work. These lists may entrain cognitive changes in the radiological work they account, for example may they over time change the way radiological staff views the division of labor. The development of lists has been a process where actors through use of lists, identifies the need for other kinds of lists. In this process lists are invented and implemented one by one. It was initially seen as a small and rather insignificant computer solution in the larger PACS. However, the working-list rapidly inspired the development of several lists. This is an example of a small solution in a larger computer system that grows and becomes more and more central. In short-term, do lists not have any large impact, but in the long-term lists may have more comprehensive impacts on social radiological work.

In all, the different lists have various implications for work. Firstly, it offers new ways to organize, share, present and communicate radiological information. Secondly, it offers medical staff new ways to support each other on. Finally, it has contributed with efficiency effects in work e.g. reducing the time required for the preparation and presentation of interdisciplinary meetings.

5. Conclusion

This paper analyzes and illustrates *how* PACS implementation and use impacts radiological work. This is of importance in the Healthcare system since the majority of hospitals in Sweden are planning the introduction of information and communication technologies.

It is concluded that in work, artefacts and their properties require that the radiologist works in a certain way. It is shown that how these properties are interpreted by its users may vary. Actors may therefore relate to and make use of the properties in various ways. The way properties are made use of may not necessarily correspond with the intentions of the designer. The impacts of new technology can therefore not be foreseen. This illustrates the importance of detailed work place studies in order to understand the impacts of new technologies. Such detailed studies may also bring forward suggestions on how to design large complex networks, as in healthcare.

This paper suggests that when analog films were replaced with PACS images the achievements in work were insignificant. The traditional sequence of activities to carry out work remained unchanged. However, the performance of most of these activities changed, i.e. substantial changes in work were identified on an activity-level.

PACS support the sharing of image information by medical staff in different places. Hence, it allows parallel work activities from practically any place where there is a link to the PACS. Working with PACS, the radiologist initiates and completes most activities related to diagnostic work, without being interrupted by another ”community of practice”. This paper illustrates how the radiologist has become less dependent on secretaries, clerical staff and assistants in work, as well as more dependent on technical staff. Since the radiologist working with PACS usually performs more tasks related to diagnostic work himself, the role of the radiologist has become less clear: a radiologist can position films and write reports but the secretary cannot diagnose an image. This is a faster way of producing the radiological report on paper, but from the radiologist’s point of view positioning films on lightboards, writing answers in RIS etc. “steals” important time from medical activities.

The increased technological span and reach has resulted in the relocation of interdisciplinary meetings to the clinical units. Previously, clinicians from various units have had a chance to meet and discuss patients. Replacing these resources has resulted in a decrease of essential inter-clinical meetings, the stability in work is in this way challenged within the hospital. To address problems of design in these changing conditions, the common recourses and their roles in work practice need to be better understood [18, 20].

In all, the different lists have offered new ways to organize, share and present information, just as it offers medical staff new ways to communicate and support each other. They were initially introduced as an insignificant technical solution. However, this solution grew rapidly and became most central in the large and complex Healthcare organization. Working with lists has improved the efficiency of various activities in work, although the overall efficiency improvements are difficult to estimate.

The perspective of PACS properties changes the prerequisites for collaborative work, not only linking technical devices together, but also the people, work practices and organizations.

Analyzing the impact of technology on work practice and interdependencies in work may be done in many different ways. In this context, it was chosen to emphasize artefacts and their properties in work. Knowledge about such artefacts appears to be of significant importance to understand the inter-relation and prerequisites in socio-technical networks.

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Paper Two

Understanding Complex Coordination Processes in Healthcare

Nina Lundberg and Hilda Tellioglu

Abstract

This paper identifies and analyzes complex coordination processes at radiology departments in Austria, Denmark, and Sweden. The understanding of coordination work is emphasized by focusing on different interdependencies between work activities. It illustrates that various interdependencies have different properties, which in turn have derived different coordination dimensions. We refer to these dimensions as predefined and situated coordination. This paper points to the needs for designing coordination tools inscribed with properties that fit the properties of various kinds of coordination work. Finally, ways of integrating these tools are discussed.

Keywords: Coordination work, ethnographic studies, Healthcare, artefacts, systems design.

1. Introduction

Coordination problems within Healthcare are increasing (Strauss et al. 1985). It is a fact that the need to coordinate and exchange information faster, better, more accurately, and comprehensively within Healthcare is becoming most evident. The improvement of radiological coordination is being conceived and implemented with the use of information technology in several hospitals. A recent inquiry illustrates that 60% of all radiology departments in Sweden are in the process of implementing picture archiving and communication systems (PACS) by year 2001 (Laurin 1998). This transition to PACS is one of the most drastic and significant changes in healthcare today. According to the general opinion great promises are related to this new technology supporting communication and coordination work. Other researchers have stated that by its nature computer technology transcends cultural, territorial, practical, and political boundaries (Dahlbom and Janlert 1996).

Hospitals are large distributed organisations containing decentralised departments. The medical staff needs to coordinate activities, for example, allocating and scheduling actors, resources, and other activities (Strauss 1985). The coordination must be accomplished through people who usually are not in face-to-face contact with each other. These factors add tremendously to the difficulty in achieving smooth coordination. When one examination drops behind, the pressures from the remaining patients are accumulated. Therefore, timing and coordination are key problems of the Healthcare organisation.

Another factor that adds to the complexity in coordination work in Healthcare is that large parts of medical work are often unpredictable, because there are so many unexpected contingencies and process complexities. For instance, a patient may develop side effects from the injected contrast medium prior to a computer tomography examination or the patient may be seriously ill, but the cause of the desease may be hard to find out, thus making the work unpredictable. Furthermore, working with people adds a dimension of hazard to the coordination work, patients may become scared, frustrated and even angry at the way a treatment or examination is being carried out or depressed by the implications of the findings.

In hospitals, radiology departments are unique in two senses; firstly, by being a service department within the hospital and secondly by being extensive users of electronic medical technology. For instance, the radiological staff pulls switches on machines and programs computers, processes data, just as they prepare and position patients to be examined. The medical specialization and technological innovation are simultaneous, parallel and interactive, creating an impetus to further technological innovation and specialization (Strauss et al. 1985). We have chosen radiology departments for our ethnographic study because it is the place in hospitals where information technology is used mostly and intensively.

We found that the coordination work was in constant change between a more or less predefined or situated coordination, due to contingencies aligning with whatever the situation calls for. It is a complex relationship, where there was no absolute coordination. We also found that different coordination dimensions were derived from the various properties and features in interdependencies. We have seen that the different properties in computer technologies supporting coordination work must fit the properties of the various kinds of coordination work. We have found that computer systems supporting predefined coordination work call for more conventional process-oriented technology. These trajectories are predefined in the system, based on known contexts and circumstances, while computer support for situated coordination calls for new inter-personal mobile technologies, in which designers are encouraged to build coordination tools supporting situations where medical staff may need to improvise coordination work and communicate in real time. The challenge is not only to design the two technologies, but to find a way by which the two are smoothly integrated and aligned in work.

The aim of this paper is to analyze and illustrate complex coordination processes in radiological work. This is done by emphasizing various interdependencies and their properties in work. We try to reveal the integral dimensions of coordination work from the point of view of those who use these technologies, fitting to the needs of users. And, as Suchman (1995) pointed out, the goal of making work visible for systems design is to develop more appropriate technologies from the point of view of those who will be using them. To make work visible is to represent work's contingent and embodied structure (Suchman 1995). Strauss et al. (1985) also pointed out that since the type of work may vary for different kinds of activities, the investigator needs to analyse the integral dimensions of work. Otherwise the analysis will fail to encompass much of the actual complexity of work that occurs in the realm of the activity under investigation.

The present study has contributed with increased understanding and knowledge of complex coordination work in large and heterogeneous organizations as Healthcare. In this work we explored the concepts of the ad hoc situated coordination (SC) and the structured predefined coordination (PC) in order to understand and explain interdependencies between radiological work activities. We believe that we, as designers, need more differentiated set of concepts to grasp the different ways the different actors handle the different situations. With this paper, we have tried to start with one of them, namely with the differentiation between predefinition and situatedness, and we hope to contribute with more detailed concepts in the future.

We have found how the different properties in computer technologies supporting coordination work must fit the properties of the various kinds of coordination work. This means that there is a need for different kinds of coordination tools because the interdependencies in work have different features and properties. For instance, the sequential interdependence is process-oriented, re-iterative and predefined and calls for a technology that aligns and supports the triggering of and control over activities guided by organizational formal structures. While the reciprocal and sometimes simultaneous interdependence is unexpected, unique and unfolding, it calls for a technology supporting improvised coordination according to unfolding events and contingencies. It involves both actors' initiative and judgement which are guided by the actors' knowledge and skills. These issues are important to consider for practitioners in the design of coordination technologies.

After describing the related research, we will introduce our research approach. In Section 4 we will present our theoretical framework surrounding coordination work by exploring the notion of predefined and situated coordination. Section 5 contains detailed description of work activities in radiology departments among which we try to analyse interdependencies before we illustrate some examples of real time coordination work in Section 6. Challenges for design of coordination technologies are discussed in Section 7. Finally, we discuss the different notions of coordination introduced and the issues for designing information systems to support coordination work.

2. Related Research

Coordination research within Healthcare has been a central issue for CSCW researchers (Strauss et al. 1985, Symon et al. 1996, Bardram 1997, Lundberg and Tellioglu 1997). In their studies of Healthcare Strauss et al. (1985), focused on the interdependence between activities in work practices, with particular focus on humans' social interaction from a patient perspective. The study highlights various kinds of work that are otherwise invisible, for instance, comfort work, safety work, articulated work, etc. It contributes with essential illustrations of social aspects of how things happen in the workplace.

The conceptualisation of ”illness trajectory” in medical work (Strauss et al. 1985) refers to the organisation of work around the patient mainly passing from admission to discharge from the hospital. Symon et al. transferred this concept to the term ”procedural trajectory” (1996, pp. 6). They analysed work practices in a hospital context in order to ascertain how coordination occurs in the relative absence of technology. They defined two different work activities, which are described as formal procedures and informal practices. The informal practices are those activities and interactions which, while not explicitly stated or prescribed by managers, are traditionally accepted as enabling the work and as being culturally appropriate. ”Around the formal procedures, coordination is achieved through experience, personal relationships and shared contextual knowledge” (pp. 28). In their case study, Symon et al. showed that the relationship between formal and informal is more complex than it first appeared. Formal procedures are defined as the correct way to conduct work. However, they are associated with a number of well-known problems, including their inability to cope with the dynamics of an ever-changing situation and to account for social and political aspects of that situation.

Our approach differs from Symon et al.'s on a number of aspects. Firstly, we analyse radiology departments in the presence of small and large-scale PACS implementations. Secondly, Symon et al. focus on what Carstensen (1996) defined as work activities around the patient as they undergo a particular medical procedure. We instead focus on the work conducted to coordinate the formal procedures and informal practices.

In the scope of ethnographic studies, Kjaer and Madsen tried to understand the role of computer applications in organisational settings (1995a, 1995b). They proposed a conceptual framework that focused on four different aspects of organisations – work activities, technical artefacts, space, and work organisation. They investigated the dependencies between these elements and tried to understand how the flexibility of one element can either trigger or constitute a barrier for change in another element (1995a, pp. 24). Our framework is also based on work activities. But we focus more on the concept of interdependencies between work activities e.g. studying the work practice by primarily the coordination work.

Based on experiences in systems design in hospitals, Bardram explored the term situated planning (1997). In his paper he discussed how plans themselves are made out of situated action and in return are realised in situ. He mainly focused on workflow systems with an activity theory approach. Workflow systems contain mechanisms giving order to work such as pre-hoc representations of medical work like plans, checklists, schedules, protocols, work programs, etc. How to handle exceptional situations and questions on how to deal with unforeseen situations have always been an issue in workflow management technologies. Bardram argues that ”breakdown situations are not exceptions from work activities but are a natural and very important part of any activity which forms the basis for learning and thus for developing and enhancing plans for future action”. In his empirical study he concludes ”the important role, which planning plays within hospital work and how a computer system was designed to support planning without emphasising rigid matches between plans as representations of work itself”.

Various kinds of coordination work have also been well described within organisational theory. For instance, Thompson described three kinds of coordination work as standardised , involving the establishment of routine and rules (1967). In our research we call this predefined coordination because the term standardised gathers a connotation of a fixed and absolute standardisation that cannot, regardless of anything, shift to another coordinated way within a given organisational structure. The second kind of coordination work is coordination by plan, involving the establishment of schedules that allows a greater extent of dynamic work. Finally, coordination by mutual adjustment involves the transmission of new information during the process of action.

In our research these two last kinds of coordination are conceptualised as situated coordination. The term “plan” gathers the connotation of established plans, which is too restricting for our purpose, just as mutual adjustment gathers a connotation which unduly requires face-to-face communication. Situated coordination may involve communication across individuals, but it cannot be assumed that it necessarily does. Thompson’s work is also different from ours by means of having an organisational perspective when defining coordination work. While we have a design perspective, aiming to understand work practice in order to inform systems designers.

To analyse work practices and design appropriate systems, the understanding of Malone and Crowstone’s (1990) interdependencies as well as of situated and predefined coordination are essential. There are distinct parallels between the different kinds of interdependencies (prerequisite, sharing of resources, simultaneously and reciprocal interdependencies) and situated and predefined coordination. With prerequisite interdependence and sharing of resources the predefined coordination is called for. Simultaneously and reciprocal interdependence is managed by the situated coordination work. These parallels will be further illustrated in the section "Real time coordination work in radiology departments"

3. Research approach

To analyse coordination patterns in work activities, e.g. in hospitals' radiology departments, we first have to study work practices. In this paper we try to emphasize interdependencies between different work activities. Our ethnographic studies give rich descriptions of work activities in hospitals with different computer use. We carried out our studies in Austria, Denmark, and Sweden. The studies offer material for further analysis of coordination issues depending on existing cultural, social, and technological circumstances. The interviews can primarily be characterised as open-ended qualitative interviews. Thirty interviews (lasting 1-2 hours) were conducted at the respective sites. We observed approximately 80 hours of radiological work. Additionally 43 hours of video documentation was recorded in Sweden. We conducted interviews while showing video documentation, which made it easier for the radiologists to describe and talk about their work practices. This also facilitated our own understanding of their work practices. We have, furthermore, spent about 120 person-hours observing the design process of PACS as well as documentation of PACS and radiology information systems (RIS). The interviews, observations, video-based work practice analysis, the integration of discussions and interviews, observations of diagnostic practice and social interactions were conducted over a period of approximately 4 months, and were followed up by several meetings, mainly with the IT-project managers.

A paperless department is defined in this paper as one where all examination requests and radiological reports are digital using RIS, while the definition of a filmless department is one where all images are digital using PACS. The definition of off-line images are 6 months or older images that are stored on portable optical discs, which are not permanently assembled on jukeboxes that allow access to images. Images stored on these optical discs must be requested via the personnel in the (central) archive, which then put the correct optical disc into the jukebox to enable access. The field studies reported in this paper were conducted at three radiology departments in three different countries:

- Lorenz Böhler Emergency Hospital, Austria This is an emergency hospital with 62,000 radiology examinations per year. On average, 290 patients are examined and treated per day. The electronic data processing department of the hospital developed a system, called ASTRA. It is the only computer system used in the whole hospital. The Lorenz Böhler Emergency Hospital is completely paperless and filmless.
- Skejby University Hospital, Denmark The Skejby University Hospital is a growing hospital with 509 beds. Approximately 34,000 radiographic examinations are carried out annually. In Skejby University Hospital,

PACS technology was introduced in 1992 for the handling of images. The department is a paper-based department, using paper documents for all examination requests and radiological reports, and almost filmless.

- Sahlgrenska University Hospital, Sweden In the Thoracic section, Radiology Department at Sahlgrenska University Hospital, Sweden, a total of about 45,000 examinations are carried out annually in the thoracic section. The radiology department is a filmless and paper-based department, using paper documents for coordination work, and communicating examination requests and radiological reports with clinical units.

4. Coordination work

We define coordination as the act of managing interdependencies within and between activities, in order to achieve a goal (Malone and Crowstone 1990, Schmidt 1993). There are three different types of interdependencies in work processes (Malone and Crowstone 1990, pp. 362). The first is prerequisite. Information is moved from one activity to the next, new information is not necessarily added, the static information functions as a trigger for carrying out different work activities. This interdependence exists in radiological work if for instance the booking of an examination has been done by the administrative staff in the clinical units. The administrative staff at the radiology department will thereafter place the examination request in a shelf reserved for a particular examination and day, without adding any new information. The glance at the shelf will trigger the radiographer to fetch the request and read the document.

Another kind of interdependence is described as the sequential sharing of resources (ibid.). Here the resources are dynamic. One actor adds information to the shared resource that is needed by the next actor to take action. This interdependence occurs in all radiological examinations. For instance, a radiologist adds information to the examination request that is both supervising and required by the next actor, or a nurse adds essential information about patient’s health condition to the examination request that is needed by other medical staff. The simultaneous interdependence is the last kind of interdependence described. It is addressed to the situations where activities need to be performed in a synchronised manner. This occurs in radiology departments in some kinds of examinations, angiography, urology, or ultrasound. Examinations, image production and handling are usually coupled with other activities like diagnosing and reporting, or discussing the treatment options with the associated clinicians. In these examinations, all activities mentioned have to be carried out simultaneously.

The interdependence between activities is derived where the outcome of one activity is necessary to the next activity, and where information is simultaneously needed by multiple actors working at distributed environments. Hence, interdependence arises when work is divided (Galbraith 1977). For instance, the radiologist can not diagnose X-ray images if the radiographers have not produced them. Before the radiologist has made a diagnosis several other departments are linked to the patient. His illness may simultaneously need the X-ray images for further treatment.

There is a difference between coordinated work that is a description of the work, and coordination work that is the process of practising coordination, or in Carstensen's terms (1996), the work conducted to coordinate work activities carried out by workers. We think that work activities are a series of tasks that, one way or the other, belong together within an activity. Coordination work is sometimes very hard to distinguish from work activities, especially in Healthcare, where several activities have been translated and merged after the introduction of computer support. Activities were prior to this translation performed by many different communities. The obvious coordination work had to carry out the medical practice. After the merge, activities are carried out by mainly one individual within one particular community. Hence, the distinction between coordination work and work activities is not as obvious as before, even if it is just as essential for the work practice. In this paper, regardless whether one or several communities perform activities, we will refer to coordination work as the work carried out to manage the interdependencies between activities.

Strauss et al. introduced the concept of unexpected contingencies in Healthcare as an important phenomenon (1985). Healthcare takes place in a work environment with activities of high complexity. The sequence of activities and how coordination is carried out can vary from time to time and from person to person. When contingencies occur in the way work activities are carried out, the various artefacts need to be re-coordinated. There is often a need for coordination towards a goal, depending upon its contingencies. Several computer systems and common artefacts used may be coordinated in an ad-hoc and improvised manner. In these situations, we call the response to the set of unexpected contingencies arising in work practices situated coordination (SC). SC contains the unfolding usage of artefacts exposed to unanticipated changes articulating the situated activities. It accommodates a wide variety of activities and behaviours that are not predefined, but must instead be viewed as a unique and unfolding in each case.

On the other hand, there is always an order of work activities over time, especially in Healthcare. Common resources have to be aligned, actors' routine work has to be coordinated according to a predefined ”procedural trajectory”. To achieve this predefined coordination (PC) is necessary. PC is a process-oriented trajectory, which creates a model of work containing a sequence of work steps. Different settings within the PC may be routed in different predefined trajectories depending upon the circumstances, which have been described in advance. PC supports the non-disruptive way of giving a chronological overview of actors' activities if it is computer-supported. PC does not allow actors to ”design work practices for themselves or others or whatever” (Bowers et al. 1995, pp. 51). For instance, in hospitals doctors have predefined the coordination of routine patient treatment, and the medical staff coordinates according to those definitions. In this coordination work the staff uses coordinating artefacts, for instance written documents as an accumulated representation of their actions that support the coordination of medical staff's activities.

The main goal in a service-oriented work setting, like Healthcare, is to establish both stability and flexibility in on-going work simultaneously. ”Flexibility concerns not the regular procedures and standard ways of doing things, but the unexpected, unprecedented, exceptional cases, situations and events that are only experienced by the people who do the day-to-day work” (Kjaer and Madsen 1995b, pp. 54). It is important that the on-going work processes are carried out continuously, and unexpected situations can be handled easily if they occur. To achieve this, predefined and situated coordination work must be interrelated to each other and coexisting within the same work setting.

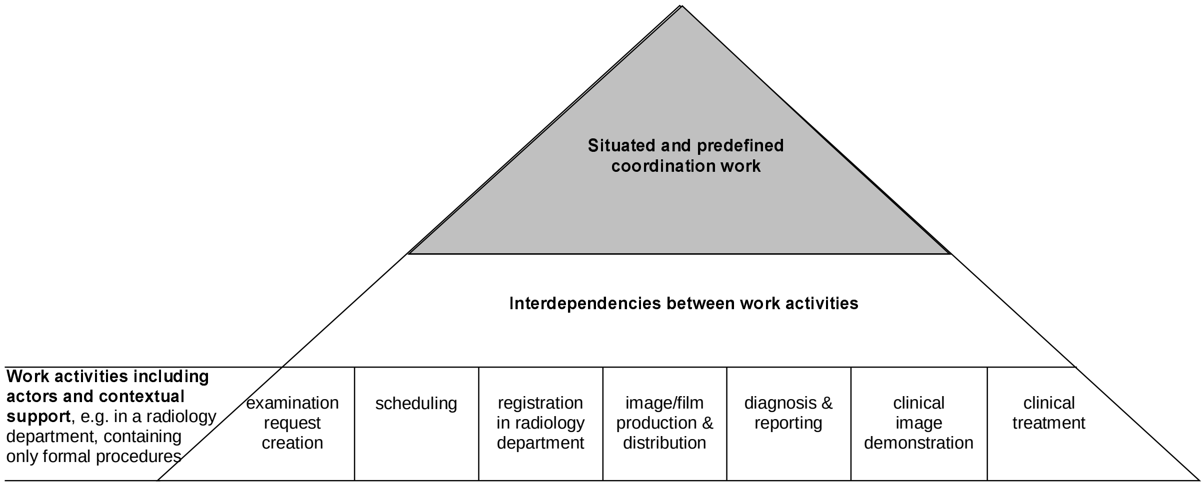

Fig. 1. Situated and predefined coordination is defined on top of interdependencies of different kinds (prerequisite, sharing of resources, simultaneous) and activities carried out in a work environment.

For instance in radiology departments, the computer systems supporting coordination work are very complex information systems, we want to illustrate in the remainder of this paper. There is a socially shared border between coordination work requiring contextual decisions and coordination work that may be managed by predefined standardised guidelines. This border may be identified through the analysis of unexpected contingencies. Designers, nonetheless, have to draw lines3. We could just imagine what coordination work would be like if the designer lacks an understanding of unexpected contingencies that influence coordination work strongly. There is a need to explore how information systems may be designed to support complex coordination processes managing interdependencies in continuously changing organisations.

5. Work Activities in Radiology Departments

This section contains a detailed description of work activities among which we try to analyse interdependencies in radiographic Healthcare before we illustrate some examples of real time coordination work in the section "Real time coordination work in radiology departments". First, we briefly describe the computer technology used to which we will refer in the presentation of work practices.

PACS support the electronic storage, retrieval, distribution, communication, display, and processing of image data. In combination with hospital information systems (HIS) and RIS it allows the management of work associated with radiological examinations in a networked hospital. RIS, which are mainly used for administrative purposes, include functions for communicating and managing patient data and examination requests sent from HIS, managing patient registration, scheduling radiological examinations, creating reports used for accounting, and producing radiological reports. The different functions of PACS can be placed into four categories (Greinacher 1994, pp. 22f):

- Administration functions. These include the users' login procedures and managing access rights, creating work folders, queuing functions for database access, creating hard copies of images, communicating with other nodes in the network, and creating work lists to manage various activities.
- Display functions. After having retrieved images from the archive (mostly on optical discs in jukeboxes) and the patient folders, users can change the configuration of the image display on their local screens without changing the original image saved on the (central) archive. They can manipulate images' grey scale, size, and orientation (rotate or invert the images), etc.
- Image measurement functions. These enable users to measure the length between image points, and to measure angles and areas on the image. Through these functions, pixel statistics and definition of specific areas that must be highlighted for observation are possible. Subtraction, addition, and density measurement can also be performed.
- Three-dimensional reconstruction. These are very useful for displaying images in stacks by scrolling between them. These three-dimensional effects are mostly used in displaying computer tomography images.

A hospital can introduce PACS in different scales. The first scale PACS consists of a conventional image production module with a digital archive unit without any network. PACS of a second scale, includes a local network connecting image production modules, the archive, the hard copy machine, diagnosis and reporting workstations. Large scale PACS are built around a network connecting many departments in the hospital. The integrated interface to RIS and HIS are available and used on a daily base. The Thoracic Section at Sahlgrenska University Children's Hospital has a second scale PACS. There is no integrated interface between RIS and HIS. However, RIS and PACS are integrated with the network technology supporting other departments. The interface has primarily been implemented by gateways, e.g. plug-ins to the Intranet. Gateways allow the information flow between systems of different technical solutions (Hanseth and Monteiro 1996). Lorenz Böhler Emergency Hospital has a large scale PACS which is the only computer system used for all activities carried out within the whole hospital. In Skejby University Hospital, PACS technology installed is a large scale one whereas there is no integration between the PACS and HIS.

PACS technology is not only an archiving, but communication and coordination system as well. Its main function is to create a shared electronic space where radiology images (connected to patients' demographic data) can be stored. Embedded in a network environment, PACS facilitate the sharing of the image data across organisational and professional boundaries. Images can be archived and organised in central units, and accessed and used cooperatively by locally distributed actors.

The actors involved in radiology are from varying disciplines and occupations: clinicians, who initiate the radiological examination and treat the patients; administrative staff, who serve as the link between the radiology department and the outside world; radiographers, who are specialists in image production and support the radiologists; radiologists, who are the "real" specialists in radiology departments; typists, who transcribe the radiologists' reports; and computer technicians, who support all the other actors with regard to computer systems.

Radiological work consists of a high degree of interrelated routine and non-routine work. In case of non-routine work the ad-hoc conversations are an important component. At several occasions, clinicians call and visit radiologists, with request form at hand to get answers to questions they have about their patients. Such ad-hoc meetings are needed whenever there are emergency cases or severe complications in the progress of patient's illness. In the majority of cases, radiologists retrieve images on PACS. In addition, radiologists may need additional film images from the archive. In acute non-routine cases, radiological staff usually receives a preparatory phone call from the emergency department or another hospital ward prior to the patient's arrival at the department. Sometimes for these instances medical staff needs to split up into small heterogeneous collaborative units, or sometimes to form more or less extensive ones. These contemporary units may need to develop rapid complex strategies. They have to make a number of innovations, which in turn provoke unexpected rearrangements of the context and content of work activities. The heterogeneous collaborative units are usually dissolved when patients have been diagnosed and their treatment has been initiated.

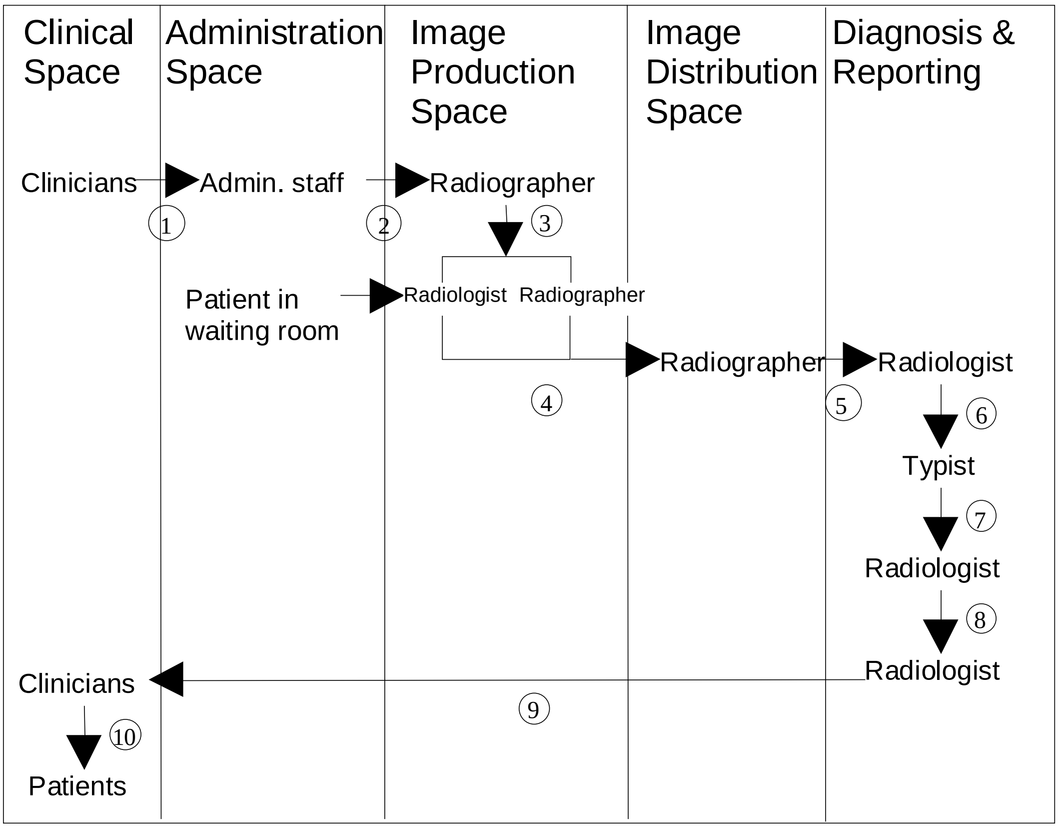

Fig. 2. Different activities in radiological work.

The enumeration refers to the activities carried out. In the radiological setting various activities need to be coordinated (Figure 2):

(1) *Examination request creation.* For a radiological examination, patients are usually sent from clinical wards, outpatient departments or primary care units to the radiology department. An examination request must be created either electronically on HIS or manually by a paper-based system. It includes data such as the patient name, date, the name of the clinician requesting the examination, the type of examination required (e.g. computed tomography, magnetic resonance, angiography, chest examination, ultrasound, mammography, etc.), and the clinicians preliminary diagnosis.

(2) *Scheduling.* After the examination request is received in the radiology department, it is categorised as acute or elective and then prioritised in time accordingly. A room and in complex cases also a radiologist are assigned to each examination. The receptionists use RIS to check whether the patients have been examined at the department previously. The demographic patient data, e.g. name, address, date of birth and telephone number, etc., are retrieved. If there are any prior examinations that seem relevant for the current exam, images from these examinations are required from the archive. *Registration in the radiology department and waiting.* When the patient has arrived in the radiology department, he/she must be registered for the requested examination by using RIS. After the

registration the patient waits in the waiting room until he/she is called for the examination.

(3) (4) (5) *Image/film production and distribution.* By using image production machines, radiographers – in the case of magnetic resonance, angiography, ultrasound, etc. in collaboration with radiologists – prepare the patient, the equipment (by means of RIS) and the room for the examination (3). They create the images/films, by using image production equipment (4), and carry out the preprocessing of the images, e.g. optimising their size, formatting, and checking their quality, before the patient leaves. Images are archived on the central server. If films are needed they are printed on a laser printer. Afterwards, radiographers must combine images/films with corresponding patient data before they distribute them to radiologists and/or clinicians via PACS (5).

(6) (7) (8) (9) *Diagnosis and reporting.* In case of partly filmless and paper-based radiology departments previous film (i.e. non-digital) images, in case there are any, must be placed onto a common place, e.g. in a trolley, in the diagnostic area, before the examination starts. The barcode on the paper-based examination request must be scanned to get an overview of the patient's previous radiological examinations. In case of filmless departments, relevant previous images must be retrieved from the (central) archive and uploaded onto the PACS-workstation for the diagnosis. Retrieving images (prefetching) can be done either automatically by appropriate algorithms implemented in the computer applications or manually by radiologists or administrative staff. If off-line images are needed, a request must be sent to the personnel in the (central) archive to put the correct optical disc into the jukebox. The latest report of the patient if there is one (in RIS) must also be retrieved. Radiologists read and compare the images to complete the diagnosis. After image analysis and diagnosis (6), radiologists dictate the report onto a tape recorder, which is later typed and transcribed by administrative staff into RIS (7). Radiologists' reports, when short, are entered into RIS directly by radiologists. The written report must be checked by its creator or another radiologist and signed in RIS (8). It can then be sent to the referring clinician to HIS (9).

(10) *Clinical image demonstration.* The majority of images and radiological reports are discussed in the daily interdisciplinary meetings between clinicians and radiologists by using PACS. Images are presented, cases are briefly described, radiologists explain their diagnosis, and clinicians discuss further diagnosis and the treatment of the patient.

(11) *Clinical treatment.* In normal cases, each radiological report is distributed to clinical wards and outpatient departments by "transporters" or via RIS

respectively. Clinicians read radiological reports and write a summary of the radiological report into the medical record. The radiographic examinations and reports make a significant contribution to the correct diagnosis and treatment of patients. After regular meetings with radiologists, images are instituted by clinicians.

Besides demonstrating the interdependencies between work activities, Figure 2 shows actors' involvement for different activities in radiological work. It is a formalised representation of the prerequisite interdependence and the sharing of resources at radiology departments. The locations at which the different activities are carried out often indicate the relationship between the activities (Tellioglu and Wagner, submitted). Clinicians work mainly on the wards and in outpatient departments. For regular meetings or in case of emergencies or particular problems they may visit the radiology department. The workspace of the administrative staff is mainly the registration or back office. Typists, who usually belong to the administrative staff, interact with radiologists in their ”territory” – in the diagnosis and reporting room. Image production and distribution are the main areas of the radiographers' work. Radiologists mostly work in the diagnosis room and enter the image production area when they collaborate with radiographers. They consider the whole radiology department as their terrain as they have overall responsibility for all radiological services. Computer technicians work throughout the radiology department depending on where problems occur.

According to Malone and Crowstone (1990) the interdependence between activities can be analysed in terms of common objects that are involved in some way in several actions. In our cases one or several common objects have been translated to allow more ready access to some patient information. For instance, X-ray films have been translated into X-ray images, and written documents have been translated to electronic documents. In work practices we found common objects as a shareable representation of work which can take many forms and serve multiple purposes (Robinson 1993). Therefore a common object such as an examination request, an examination schedule, a ”to-do” or patient list categorised by the examination type needs to be accessed by many different actors in multiple contexts and under different circumstances. A radiological report may also show the work done in radiology departments by offering an overview of the sequence of work activities. These representations support the implicit communication of suggestions for the diagnosis, which can take the form of a textual remark, a sign on the image, or an annotation to communicated documents.

6. Real Time Coordination Work in Radiology Departments

The following examples illustrate how coordination is managed in particular activities and in the overall work flow.

6.1 Coordination work surrounding radiological work at the Sahlgrenska University Hospital (SU)

At SU an examination request is created on HIS and printed on paper. It includes patients' demographic data, the name of the clinician requesting the examination, the type of the examination required, the patients' symptoms and the clinicians' preliminary diagnosis. When the examination request is received in the radiology department, it is scanned into the RIS system. This enables the radiological staff to access all medical data of the patient via the RIS and PACS. The request form is thereafter put into a shelf. If there are any prior examinations that seem relevant, images are requested from the film archive. The films are transported in trolleys from the file room to the radiology department. In practice, unfortunately, some clinicians or radiologists may keep some films after patient diagnosis, instead of bringing them back to the archive, which causes interruption in the routine work.

The day before the examination is taking place the examination request is placed in a trolley (see Figure 3). The trolley is organised according to examination types and time schedules. A glance into the trolley gives an overview of the day's schedule and workload.

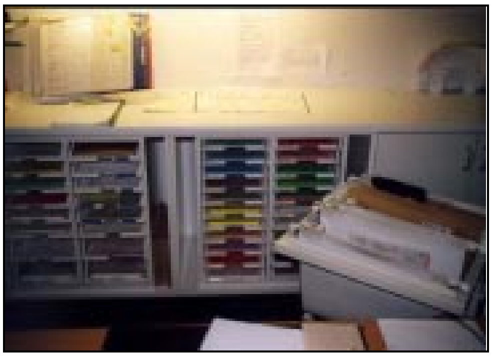

Fig. 3. Trolley organising the examinations during a day and shelves with documents showing the workload and enabling the distribution of work between actors.

When the patient arrives in the radiology department, she is registered for the examination. The patient then waits in the waiting room. The radiographer fetches the examination request from the trolley, prepares the patient for the examination and creates the images. She views and selects the PACS images, adjusts the density level to produce the optimum image, performs any reorientation and annotation which is necessary, and then verifies the examination. When images have been verified, PACS automatically transfer them to a folder, containing the 1,500 most recent radiological examinations. Thereafter, she places the paper examination request on a table visible to the administrative staff. When an administrative employee sees the document, he/she distributes it manually to the shelves in the diagnostic area, visible to radiologists (Figure 3).

Radiologists can see how big the piles of requests in the shelves are while reading PACS images from a workstation in the image interpretation area. When it has reached a certain size – which depends of the degree of urgency of other tasks – radiologists fetch piles from the shelf and sit in front of one of the PACS workstations to carry out the diagnosis. All workstations are provided with infrared barcode readers. Radiologists fetch patient data onto workstations by ”swiping through” a barcode-encoded ID sticker attached to the paper request. When all barcodes have been swiped through, a “work-list” has been generated. After selecting a patient in the work-list with paper at hand, radiologists read and compare images on screens and light boards to complete the diagnosis. Radiologists’ reports, when short, are entered directly into the RIS by radiologists themselves. They print the reports on a laser printer and put them into a plastic folder together with the paper request and place them on shelves accordingly.

In case of a long report, radiologists dictate their reports on tape and place it together with the paper request on a table. When a typist sees them, he/she transcribes the reports on RIS, prints them on paper and places them on the radiologists’ shelves to be signed off. Radiologists complete the report-checking activity by placing the written report on a shelf labelled with ”out” to the medical department. Radiographic reports are picked up by transporters in the out-shelves and brought to the referring departments.

This case illustrates the predefined coordination work of several work activities such as scheduling, patient registration, X-ray image production and distribution. The sequential sharing of the written examination request is managed by its placement on a table in the reception of the radiology department, its distribution to a shelf in the hallway outside the image production room, its distribution to another table in the diagnostic area, etc. The sequence of work steps is very clear to all actors involved. Each actor is dependent on the information produced by the actor in the subsequent activity. The case shows that wherever the written document is placed in specific locations, it represents signals, which trigger action. The written documents’ appearance also provides a good overview of the work progress.

6.2 Coordination work during a chest diagnosis at the Sahlgrenska University Hospital

This case illustrates the radiologists’ work in diagnosing a chest examination.

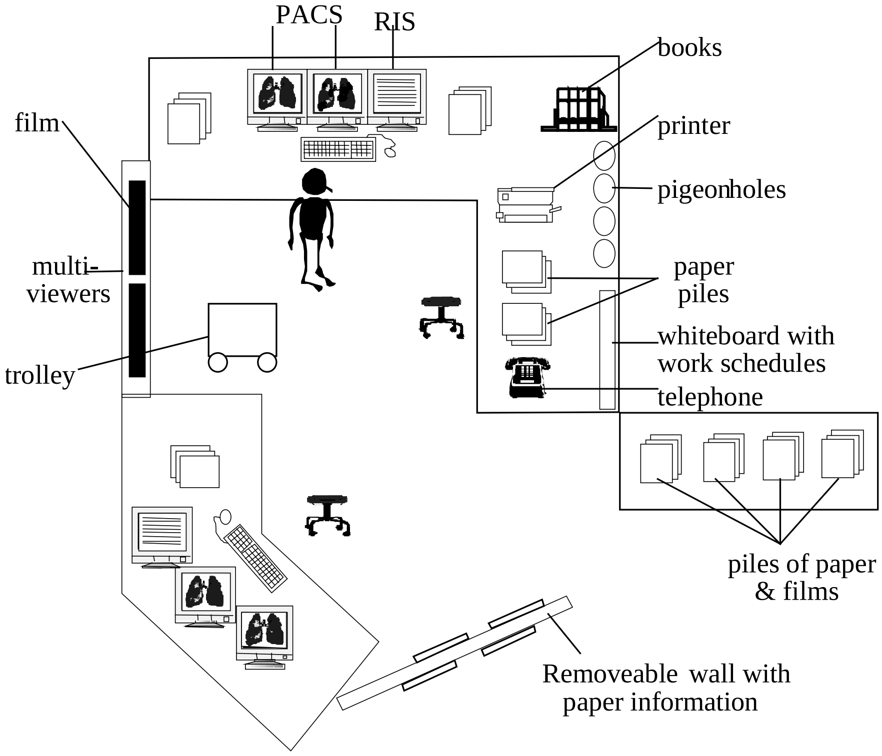

Fig. 4. Graphical illustration of the setting.

The radiologist is working in the diagnostic area (Figure 4). Diagnosis of a chest examination has been requested by a clinician of a patient selected by the radiologist in the work-list.

Fig. 5. A radiologist reading PACS images.

The radiologist zooms and uses the tools provided by PACS to magnify and change the contrast of images. The manipulation of images allows a range of densities to be seen in the image, just as it allows the instant measurement of various findings. Images are compared through the shift between images showing different views of the patient's chest (Figure 5). He looks again at the electronic request and realises that there are some old X-ray films from an earlier examination. He leans over the trolley behind him and looks for the films, but the required films are not there. He stops one of the administrative staff who is walking down the hallway and asks her about the films, but she cannot assist him in this matter. He picks up the phone, which is located on a table behind him, and calls the (film) archive to ask them to send up the appropriate films. He requests a secretary to bring the films from the film archive. He places the chest examination request in a pile called “wait”, awaiting the old films. Fetching and positioning old films from the archive may take anything from 15 minutes to half a day depending on the urgency of the case. The film images that need to be compared may be anything between 2 and 150 images, positioned on one or several light boards.

Meanwhile, the first patient is placed in the “wait” pile, a surgeon is visiting the radiology department unexpectedly. He needs to discuss a patient of his with the radiologist. The radiologist retrieves the PACS images related to the surgeon’s patient on one of the workstations. Suddenly, a transporter arrives with the missing films from the first patient (currently placed in the “wait” pile). The radiologist asks the transporter to put the films on the table by the lightboard. He walks out into the hallway and asks an administrative staff to support him positioning the X-ray films just delivered from the archive. He returns to the surgeon and apologises for the interruption. The radiologist and surgeon continue their discussion of the treatment of the patient. They decide that no further radiological examinations should be made prior to patient surgery. In complex conditions like this, there is no straightforward way to treat patients. When discussion is completed the surgeon returns to his ward. The radiologist walks over to the “wait” pile and fetches the first patient’s examination request. All old films are now positioned on the lightboard, he reads and compares the images on screens and light boards to complete the patient’s diagnosis. The radiological report is long, so the radiologist dictates the report on a tape recorder.

There is a phone call from the emergency department, informing the radiologist that an emergency patient is arriving shortly. The radiologist needs to rapidly compose a small heterogeneous collaborative unit. But who is working where, with what, he needs to improvise, make phone calls, get support from other staff to locate medical staff. The contemporary unit needs to develop rapid complex strategies, they have to make a number of innovations, which in turn provoke unexpected rearrangements of work context. The heterogeneous collaborative unit is dissolved when patients have been diagnosed and treated. Everything returns according to the examination schedule.

It is time for lunch, so he glances at the schedule on the board on the wall behind him to find out who is working where, and then joins one of his colleagues for lunch.

The radiologist had his own ad-hoc order of coordinating things, such as discussions with the clinician, searching for X-ray films, computer work with PACS and RIS, discussions with administrative staff, lightboard and diagnostic work. All these steps are at the same time documented in the artefacts implicitly. In case of uncertainties the radiologist could refer to these artefacts and to the very detailed data they include.

The situated coordination of several reciprocal interdependent activities within the diagnostic practice was illustrated in this case. The radiologist had to coordinate related activities, surrounding PACS and RIS, films, medical requests, discussions with the clinician as well as other medical staff, telephone calls, etc. in an order adaptable to contingencies to convey the diagnosis. This coordination is by its nature situated and relying on the individual coordination of the radiologist. It was not determined by formal a priori needs.

6.3 Coordination work during diagnosis in an emergency case at the Lorenz Böhler Emergency Hospital

After registration the patient is taken to the image production room where images are created and saved on the central ASTRA server. The patient, now in the diagnosis room, sits in front of the radiologist. The radiologist loads the new images onto the ASTRA workstation, which has two monitors. Further to his right there is another ASTRA station where an experienced secretary is preparing the reports. Each step is predefined: she retrieves the patient data, opens a new folder for the new report, and types the radiologist's full name and some other codes that identify the type of examination which indicates the costs. He can see and follow each move she makes by means of an additional third monitor located on the right-hand side of the workstation. He uses the mouse to zoom in on the image on one of the screens, and to change the contrast. The patient says he has brought his old films with him. The radiologist decides that he does not need to see the old images, as he knows what the diagnosis and treatment will be. He then starts to dictate the report, and the secretary types it simultaneously. He follows the text on the screen and corrects the last sentence verbally. She changes the sentence literally on the screen. He tells the patient what he has to do next. The secretary sends the report to the printer next to her. She then gives it to him who signs it and hands it to the patient. The patient leaves the room, with the whole procedure having taken only 4 minutes.

The coordinating steps during the diagnosis are predefined, through inscriptions in the computer applications (ASTRA), in order to manage the interdependence between work activities by sharing resources. Images are displayed on the screen by the radiologist. At the same time, ASTRA performs the necessary actions required for diagnosing step by step, such as retrieval of patient data, opening a new folder for the new report, showing old reports to the radiologist, etc., and waits until the required data are entered by the secretary accordingly. ASTRA displays a work trajectory, it helps keep things on track.

The cooperation between the radiologist and the secretary is driven by actions, which must be taken during the whole process. The work tasks are clear to both actors, and the process progresses very quickly which is strongly required in emergency hospitals. This example shows that the artefact, in this case the PACS technology (ASTRA) has control over the actors' work order. This control could also be inscribed in an analog technology such as a paper document. The predefined coordination guided by the organisational (formal) structures happens in a stable, robust, and inflexible milieu, where scripts/documents have a predefined trajectory, i.e. the work sequence is predefined.

6.4 Coordination work during an unexpected urology examination at the Skejby University Hospital

A nurse from an outpatient department calls a member of the administrative staff in the radiology department. A clinician needs a urology examination unexpectedly on the same day. Normally the waiting time for a urology examination is several weeks.

The administrative staff in the radiology department uses her computer to administer time schedules of all examinations carried out in the department. She accesses the time schedule of the urology examination rooms and enters some identification codes and the current date in order to search for an available time slot. The computer system (RIS) suggests the next available schedule on the screen. A urology examination takes about 45 minutes, which is calculated by the computer before the time slot is suggested. Sometimes, there are gaps in the system because a patient did not arrive. The administrative staff can modify the system and enter new patients in these time slots. An available time slot was found. She informs the nurse who is still holding the line, and she books the room for the examination.

The requesting outpatient department then sends her an official request form. A porter brings these forms to the radiology department three times every day. She makes a note and puts the date on it showing that the examination has already been booked. She puts the form onto a shelf, which doctors check regularly. She then prints out the list of all patients who are going to be examined on the same day. This list is accessible to all actors in the department.

The administrative staff had to handle the scheduling system RIS with the telephone call from the outpatient department, when a clinician wanted to book a urology examination urgently. In this activity she had a structured and predefined way of conducting the activity in the RIS, entering the identification codes and current date. The system responded by suggesting the next available slots. She confirmed one available slot and thereafter booked a room for the examination. This example also illustrates a situated coordination by showing how the overall discussions and artefacts are coordinated to convey the booking of an unexpected examination.

7. Challenges for Design

Translating the coordinated role of paper documents and other linked artefacts to computer systems is a challenge. Because, artefacts are not just individual objects, they are part of a shared infrastructure that all radiological work depends upon (Hanseth and Lundberg, submitted). Shelves, folders, trolleys, tables, and mailboxes are all designed to fit the examination request, just as the paper request is designed to fit coordination and communication needs in medical work (ibid.). To address problems of design, the links of artefacts in work practices need to be better understood – even if only to explain what life will be like without them (Lundberg and Sandahl, submitted). Translating paper-based examination requests to computer systems means that the coordinated role of the paper document must be overtaken by information systems. For a large network as implemented in healthcare, it will in practice become impossible to coordinate all actors to switch from one coordinated network to another at the same time (Hanseth and Lundberg, submitted). The large coordination network, linked to many other artefacts, cannot be changed instantly. It can only be changed in a process where smaller parts – sub-networks – are replaced by new ones. The networks need to be convergent and aligned. One way to align heterogeneous sub-networks is to introduce interfaces – gateways – between them (Hanseth and Monteiro 1996). If, for instance, gateways were designed between all hospital information systems, they could keep track of a unique patient identifier that could apply on all hospital services (Lundberg, submitted). If there would be no interfaces between the information systems used patients could have several identifications (IDs), according to a complicated trajectory related to the units where they had been registered, e.g. in the emergency, the radiology, the surgery clinics, or in an inpatient ward. To coordinate a patient trajectory supported by more than one local information system, which are linked via gateways, becomes very complicated.

Through this study we can identify two sub-networks to be changed. The first sub-network contains the interplay of the paper-based examination request with different artefacts, for instance, shelves, tables, trolleys etc. supporting predefined coordination work. Systems like ASTRA (used at the Lorenz Böhler Emergency Hospital) must be extended to provide more transparency and awareness of interdependencies within the predefined structure of the work. By means of a sophisticated display mode which is accessible from all work stations, it can be possible to inform the medical staff of the work status while they are moving within the radiology department. This can be implemented as a large screen virtually representing tables, shelves and the pile of requests in the reception, image production or image interpretation area in the radiology department. For instance, a radiologist can automatically be informed about the reception of an urgent request. A similar display mode can also be introduced at clinical departments, in order to represent e.g. the "in-shelves" and the received radiographic reports inside them. In these cases, the display modes on large screens (both in radiology departments and clinical areas) can be considered as gateways.

The second sub-network is the net of resources supporting overview and awareness in the situated coordination, in which unexpected contingencies in work processes requires ad-hoc arrangements of contemporary groups and collaborative work. To support situated coordination, a small mobile computer device, like a palm pilot, can be introduced. These devices can be granted to radiologists and clinicians, in similarity to their personal callers. The applications available on these devices should support inter-personal awareness, in similarity to the Internet application ICQ (“I seek you”). Such a mobile system could give the medical staff information of who is available at work and more importantly, it could get messages across in real time. The system could use sounds or vibrations to notify medical staff when something is happening. The medical staff can send messages or files, e.g. the medical history of a patient. Similar to ICQ, the system must also make it possible to be invisible to other users. This is important and necessary, because some medical work does not allow interruption.

As shown by several ethnographic case studies, informal practices are as important as formal procedures. For instance in radiology departments this speeds things up (Symon et al. 1996, pp. 23). ”It is likely that any computer-based system which forces participants to adhere to formal procedures and inhibits informal practices would ultimately disrupt the work activity” (pp. 25). We need technical infrastructures, which support both modes of working, enabling switching between working within the predefined procedural trajectories and working informally dependent on the current situation.

We have in this paper seen an opportunity to illustrate how different interdependencies derive complex coordination processes. It was found that coordination work is in constant change between a more or less predefined or situated coordination, due to contingencies aligning with whatever the situation calls for. Designers are encouraged to build coordination tools supporting situations where medical staff may need to form ad-hoc collaborative units, just as they are encouraged to build systems that do not allow actors to design the coordination of work activities. The trajectories are instead predefined in the system.

The ethnographic studies within healthcare have enabled us to reflect upon the larger issues of the relationships between fieldwork findings and how different kinds of interdependencies can be supported by various computer supported coordination tools. There is a need for different kinds of coordination tools because interdependencies between different work activities have different properties. For instance, the interdependence involving the sequential sharing of resources is process-oriented, re-iterative and predefined, and calls for a technology that aligns and supports these features. This can be a technology supporting a particular structure in a stable, robust, and inflexible milieu. While the properties of the reciprocal and sometimes simultaneous interdependence are unexpected, unique and unfolding, they call for a technology supporting improvised coordination according to unfolding events and contingencies. In this work we have seen that computer systems supporting coordination work call for both new mobile technologies and more conventional process-oriented technologies. The challenge is not only to design these two types of technologies, but also to find a way in which the two are smoothly integrated and aligned in daily work.

8. Discussion

Coordination work has for a long time been a central issue within the information systems design. In spite of this there are few existing technologies supporting the coordination of work activities, at least within Healthcare. We have asked ourselves what makes these systems so difficult to design? There are no simple and straightforward answer to this question. However, one of the aspects we regard as central is the lack of detailed understanding of complex coordination work in which we stress the understanding of:

- Different interdependencies in work, deriving various kinds of coordination dimensions,
- how coordinated artefacts are linked to other artefacts used in work processes,
- resources invested, by means of knowledge and skills, in order to use coordinated artefacts,
- how spaces have been shaped according to the coordinated artefacts' properties and relations, and
- the way work practices have been shaped according to all artefacts and interdependencies.

We believe that such a detailed understanding makes it possible to generate design ideas to develop computer support for coordination work.

We have observed that many distributed, intertwined, and interdependent work activities need to be coordinated in order to make the schedules in time. In practice, moving documents from one table to another, inscribing documents with medical information, making phone calls, using boards to support the scheduling of medical staff, etc. deal with different kinds of interdependence and support different types of essential and complementary coordination.

Coordination work involves both actors' initiative and judgement which are guided by actors' knowledge and skills, and artefacts trigger activities guided by organisational formal structures. The paper-based artefacts are used for coordination of an increasing number of actors and activities, and therefore becomes harder to replace with new computer-based artefacts.

In our cases the coordination work surrounding the patient was carried out in a more or less predefined or situated way. We have seen that predefined coordination was derived from a sequential interdependence, the process-oriented coordination work containing scheduling, registration, image production, diagnosis, etc., while situated coordination was derived from a reciprocal and sometimes simultaneous interdependence, involving a large number of contingencies. This is also confirmed by Strauss et al. (1985) who argue that coordination is needed when the activity is exposed to a high degree of unexpected contingencies. In SC contingencies are not planned but well known that they can occur at any time; for instance, all emergency cases, the patient may become more seriously ill, new or other radiological examinations than those available may be required, a clinician may suddenly need a diagnosis of a severely ill patient, ad-hoc telephone calls must be answered, improvised medical support may be required, etc. This implies that in the SC it is the person who initiates and make decisions of unfolding coordination work. In the PC it is the artefact (written or digital document or a function of the computer program) which indicates that the (computer or predefined workflow) system exerts control over actors' work.

In the case at the Skejby University Hospital the urgent urology examination needed by a clinician changes the handling of scheduling procedures at the radiology department. The scheduling task is usually the responsibility of the computer system used (RIS). But, in an exceptional situation the administration staff can change the order of work to book an examination. The flexibility is given by the computer system. This means that a situated way to coordinate must coexist and complement work that does not follow the predefined path, in order to maintain stability.

We have seen that diagnostic coordination work at the Sahlgrenska University Hospital is supported by very general plans. These plans recommend how radiologists are to initiate and accomplish coordinating decisions dependent upon contingencies in events. Radiologists must accomplish considerable coordination work that is very time consuming, for instance, coordinating the ordering, positioning and reading of films/images with telephone calls, discussions, improvised teambuilding, etc. However, in the case of the Lorenz Böhler Emergency Hospital the former general plans have been translated into formalised procedures inscribed in the PACS technology (ASTRA), e.g. the coordination work including predefined coordination has here been a priori inscribed in the computer system. This of course improves the efficiency of work.

Since most hospitals have been using information systems (e.g. HIS) for several years, there is a common problem in radiology departments to integrate these old systems with the new technologies like PACS or RIS. The integration problem has another dimension which is based on the interfaces between PACS and RIS, supporting more or less of PC and SC work. All these systems should be designed as complementary and supportive to end-users, since it is the integration of these systems that is the "system" in on-going work practices. The PC is made of fully rationalised typologies, and the SC supports "heterogeneity and practicality of organizational life" (Suchman 1994, pp. 178). SC must be open to uncertainties, heterogeneities, and practical expediencies.

The shift in between different coordinated modes indicates that the contextual support of coordination work needs to be flexible, supporting whatever the coordinated situation calls for. According to Schmidt and Simone (1996) particular artefacts are introduced in order to manage the coordination in work. In the SU case the examination request has developed into an important common coordination object in two senses. First, written documents' material and visible presence on a shelf or on a table (according to their structured trajectory in a medical department) allows the linking of actions and events over different sites and times without personal interaction between actors. The paper acts as a token and the shelf on which the documents are placed represents the state of work (Lundberg and Sandahl, submitted). This does not only mean that particular coordination artefacts support coordination, but also, that some artefacts support coordination in itself. Secondly, the radiological request is formatted in ways that trace work, which enables various communities of practice to coordinate particular activities among themselves. This is done in such a way that one actor adds information to the radiological request that is both supervising and required by the next actor in order to take action. The coordinated role of the radiological request is crucial in the progress of work in the radiology department. It is essential by means of "keeping the work practice together".

9. Concluding Remarks

This paper analyses and illustrates how several issues such as moving of documents from one table to another, the accumulation of medical data in documents, phone calls, face-to-face discussions and the use of boards to support scheduling influences different kinds of interdependence in medical work. Furthermore, it shows how the properties of these interdependencies call for different dimensions of coordination work in hospitals. We have briefly referred to these dimensions as situated and predefined coordination. The SC focuses on what is specific and heterogeneous in coordination work. It is the improvised response to a set of unexpected contingencies arising in medical work practices. We have seen how the radiologist had to coordinate related activities, e.g. phone calls, face-to-face discussions with clinicians as well as other medical staff, reading of films and paper requests in an ad-hoc order to make the diagnosis. The PC focuses on the standardized order and recording of work activities over time according to a predefined trajectory. It is guided by the organisational (formal) structures, in a stable, robust, and inflexible milieu, where scripts/documents and the work sequence have a predefined trajectory.

In our cases we have illustrated how a more predefined way of coordination work is required to shift to a more situated way of coordination work in order to manage various interdependencies in work. The ability to shift in between different modes of coordination work is important in work practices. Considering coordination work as a predefined process-oriented work is too restrictive if we wish to understand complex coordination processes. To address problems of systems design in changing organisations, the unexpected contingencies and their role in complex coordination processes need to be better understood as well. In this process we stress the detailed understanding of interdependencies and links in work and the ways work practices, spaces, knowledge and skills have been shaped accordingly.

We have found how the different properties in computer technologies supporting coordination work must fit the properties of the various kinds of coordination work. This means that there is a need for different kinds of coordination tools because the interdependencies in work have different features and properties. For instance, the sequential interdependence is process-oriented, re-iterative and predefined, calls for a technology that aligns and supports the triggering of and control over activities guided by organizational formal structures. While the reciprocal and sometimes simultaneous interdependence is unexpected, unique and unfolding, it calls for a technology supporting improvised coordination according to unfolding events and contingencies. It involves both actors' initiative and judgment which are guided by the actors' knowledge and skills. These issues are important to consider for practitioners in the design of coordination technologies. In addition, this paper illustrates how detailed work place studies generate ideas that inform designers.

We have contributed with the understanding of complex coordination work in large and heterogeneous organizations as healthcare. In this work we explored the concepts of situated and predefined coordination in order to understand and explain interdependencies between radiological work activities. We believe that we, as designers, need more differentiated set of concepts to grasp the different ways the different actors handle the different situations. This may be important in the design of computer support for coordination work in any organisation, not only in Healthcare.

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Paper Three

What do artefacts mean to us in work?

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Abstract

This paper illustrates how artefacts are active elements in the relationships of people and between people and their environments. This does not only mean that they are active in the sense that they are necessary, but also, active in a way that coordinate, and even trigger or initiate, work. The use of artefacts may over time become manifold and not necessarily just serving their initial purpose. We have analyzed and identified how the roles of an artefact shift in different contexts and on what grounds these roles can evolve. In addition, we combined the “Actor Network” and the “Borderline Issues” perspective to evaluate how this combination can improve our understanding of people and things in work situations.

Keywords: Artefacts, Documents, Work Practice, Actor Network Theory, Borderline Issues.

1. Introduction

«If we took away my computer, my colleagues, my office, my books, my desk and my telephone, I would not be a sociologist writing papers, delivering lectures, and producing «knowledge». I’d be something quite other - and the same is true for all of us» (Law, 1992). No doubt artefacts play an important role in our lives and in our work practice. They are initially brought into our organizations for a specific purpose, however, their use may over time become manifold and not necessarily just serving the initial purpose. Design and development of artefacts go hand in hand with the development of work practices (Suchman & Trigg, 1991). The artefacts in use are resources that communities of practices rely on. However, some of these resources may be “invisible” for designers or other outsiders. In work, rules and conventions develop around the use of artefact over time, this gives them their local meaning within a community of practice (Brown & Duguid, 1994). These resources and conventions are easily overlooked due to their highly local establishment.

By focusing on artefacts and our interactions with them resources are made visible, seen and talked about in order to inform design. Two case studies are presented. The first case is a news agency in Norway and the second a Healthcare institution in Sweden. Both cases illustrate how artefacts, for instance fax machines, fax sheets, coordination forms, examination requests, different types of shelves and tables, as well as computers - interrelate and interact with people and how this establishes recourses over time that the communities of practice rely on in the production of the desired results, i.e. TV schedules and radiological diagnoses.

We have observed that artefacts, e.g. documents have similar meanings and roles in spite of organizational differences. The news agency are concerned with TV information, faxes and schedules, whereas the Healthcare institution deals with patients, medical records, images and image production technology. However, in both cases, documents get roles that are not necessarily expected.

The aim of this paper is to analyze and illustrate *how* artefacts', e.g. paper documents get roles in various contexts. The aim is also to evaluate the combination of the Actor-Network and Borderline issues perspectives in order to gain a better understanding of people and things in a network. The focus is on how artefacts, depending upon their properties, are interviewed and embedded into work.

We have contributed with the understanding of document's roles in large and heterogeneous organizations as a news agency and as a hospital. In this work we identified that the documents are not only used as a tool and a medium, they also have roles such as a coordinator, a trigger of action, a supporter of overview and awareness, an actor, a supporter of organization of work etc. With this paper, we have tried to contribute to the understanding on what grounds these roles become embedded in work practice. In addition, this paper analyze and illustrates how the combination of "Borderline Issues" and "Actor Network Theory" may be useful in the understanding of artefacts meaning to us in work.

We have identified how the different properties of paper documents are made use of in various settings. For instance, when the paper document is used as a tool and medium an important property of the document is that it consists of information and that this information is sharable across time and space. Contrary, in cases where the paper documents has a role as a coordinator the information sharing aspect is not as important as the properties of being light, visible and tangible, because this supports the distribution and placement of paper documents at tables, in shelves etc. The same is true for the situations where documents have an initiating or triggering role etc. These roles of paper documents are important to consider for practitioners in the design of electronic documents not just in the news agency or in the hospital but for any organization in which there is a translation from paper documents to electronic documents.

The remainder of the paper is organized as follows. In the second section the related research is presented. The third section present our conceptual framework based on concept from actor network-theory and borderline issues. They are chosen for their ability to highlight the properties and features of written technologies in socio-technical networks. The fourth section presents research approach and work settings. The next section describes the cases. The sixth section analyzes and illustrates the shifting roles of paper documents while the next section analyzes how the document's roles are enabled in different contexts. The seventh section discusses artefact in work practice. Finally, the combination of the two theories applied discussed and conclusion are presented, respectively in section eight and nine.

2. Related Research

In systems design, it is common to consider artefacts as tools or media for human activity. When artefacts in general are viewed from the perspective of their use, they can both support communicative and instrumental activities, and they can mediate our activity towards other humans or towards "objects" (Ehn, 1988). An artefact can augment and even replace individual or cooperative human activities (ibid.). Ehn (1988) has an Heideggerian perspective on artefacts, which means that an artefact, e.g. a hammer, belongs to the "background", it is ready-at-hand without reflection in the carpenter's world. It must primarily be understood as a practical artefact that she uses in her everyday life, not as a thing or an object external to her. This tool perspective of artefacts is applied in research projects within the system design field where the issues are cooperative design of computer artefacts (see e.g. (Bødker et al., 1991)). The users are included into the design process based on the motivation that artefacts as such have no meaning; they are given meaning only through their incorporation into social practice (Ehn, 1988).

Investigations into work practices in operations and control rooms have uncovered the various meanings of artefacts in some respects. In their study of an airport operation room Suchman and Trigg (1991) point out the important role of the paper sheets they use, and stress the difficulties involved in replacing this paper sheet with a computer based representation. Electronic representation has some benefits. However, computerized forms have their own problems; for example, they don't allow the same ease of document transfer (Ibid.).

In control rooms such as air traffic control rooms (Hughes et al., 1994), the London Underground (Heath & Luff, 1992) or the Paris Metro (Fillipi & Theureau, 1993), the co-location of workers allows them to observe each other and to monitor the work in progress. By looking at each other's radar screens as well as listening to colleagues' conversations, they improve their understanding of what is going on, and this is necessary for the workers to carry out their own work. These studies show that artefacts are important in the «understanding of the activity of the others, which provides a context for your own activity», defined as awareness by Dourish and Bellotti (1992). We focus on how different artefacts are introduced, arranged and co-developed over time within the work itself.

In a more theoretical way, Brown and Duguid (1994) stress the artefacts' social and material aspects in the framework of their "Borderline Issues", and Latour (1987), Callon (1986), Akrich (1992) and Law (1992) point to the artefacts' properties and features in socio-technical networks. These issues are elaborated further in the following section.

3. Conceptual Framework

In order to improve our understanding of artefacts in work practice, we apply some concepts from Actor Network Theory (ANT) (see e.g., Latour (1987), Callon (1986), Akrich (1992) and Law (1992)) and "Borderline Issues" Brown and Duguid (1994). It has been important for us to find concepts that take artefacts seriously into account and make them explicit in social arrangements.

ANT recognizes that establishing and changing a social order relies on a tight interplay between social and technical means. ANT argues that society would not exist if it were simply social. Humans and things are regarded as "equal", and are treated in the same way. ANT says that there is no reason to assume, a priori, that either artefacts or people in general determine the character of social change or stability (Law, 1992).

According to ANT, social settings or work practices are nothing but patterned networks of heterogeneous materials (Law, 1992). This heterogeneity emphasizes the significance of artefacts in work practices. The concept of network focuses on interconnections and relationships between humans and artefacts. The notion of inscription refers to the way artefacts embody patterns of use (Akrich, 1992). Inscriptions can be properties, i.e., features, characteristics, and possibilities inscribed in artefacts as well as meetings, institutional arrangements, skills, etc. How these properties are perceived depends upon the interpreter and her context. Inscriptions shape the connections between different actors and therefore influence the actors' performance.

According to Brown and Duguid (1994) artefacts have both central and more peripheral properties. What is recognized as a central or peripheral property varies within different communities of practice. What Brown and Duguid (1994) define as "Borderline issues" are shared resources that constitute a social meaning for a group of people. The meanings are based on continuously presence of the artefacts in a community of practice. Continuity is needed in order to recognize the artefacts' properties, and community of practice is necessary for members to share, recognize and reformulate conventions (Ibid.). These resources are developed over time as artefacts are integrated into current practice and social conventions are developed. Communities of practices maintain the resources, and workers often rely on them (Ibid.). The importance of the peripheral properties is often unnoticed for outsiders.

We will in this paper try to combine these theories to grasp a more detailed understanding of artefacts and their meaning in work. The combined approach of theories is based on the fact that “Borderline Issues” focuses on identifying both central and peripheral properties of artefacts, while ANT support us in identifying these properties according to a context. We believe that understanding and identifying properties in these senses are important because it illustrates how the artefact’s properties are significant for its application, and how they are linked to humans and other artefacts in socio-technical networks. Over time, conventions will grow around the artefacts’ peripheral properties and become resources in the socio-technical work practice. Finally the combination of these theoretical perspectives for analyzes of empirical work be discussed in the end of the paper.

4. Research Approach and Work Settings

The studies were conducted at a news agency in Norway, a company providing news services to the media - such as newspapers, magazines, radio and television; and in the radiology department of a hospital in Sweden. The radiology department is a diagnostic center at the hospital, giving service to all other departments within the hospital.

Our research approach is built upon in-depth case studies at the news agency and on ethnographic studies at the radiology department. Both studies included interviews and observations of work practices. The interviews can primarily be characterized as open-ended qualitative interviews. Totally, 23 interviews and 70 hours of observations were conducted at the news agency, while approximately 30 interviews and 40 hours of observations were conducted at the radiology department. Each of the interviews lasted from 30 minutes to 2 hours.

At the news agency, the production of TV schedules was studied. A TV schedule consists of information about TV programs and when they start. The production of TV schedules starts with the production of TV program information from each TV channel. The information is sent from the channels to the news agency on faxes. At the news agency the process continues with quality control, merging and coordination of the information, as well as typesetting of eight different types of schedules. It ends in a variety of weekly products to be delivered to various newspapers and magazines.

At the news agency there are 6-9 people working with the production of TV schedules the entire week. The information on the fax-sheets is entered into a mainframe system that keeps track of the program information for each channel every day of a particular week. The schedules are formatted in a desktop program on Apple computers and delivered to magazines and newspapers by use of ftp. All of the employees perform the entering of information into the system as well as the formatting of schedules.

Once a week newspapers and magazines have TV supplements for the following week. However, which days this week covers vary from newspaper to newspaper and from magazine to magazine. Some offer a week lasting from Sunday to Saturday, while others present it from Monday to Sunday, according to the day the supplement is published. The huge amount of faxes, the different time frames for different publications, as well as the various types of schedules, make the coordination of work quite complex within the agency. A coordination form is applied in order to deal with this complexity.

The radiology department is a service unit, carrying out radiological examinations for clinical departments inside the hospital, other hospitals and primary care units (general practitioners). The radiology department supplies radiological opinions on, and interpretations of, radiological images ”delivered” to clinicians by means of reports and meetings. The radiological examinations and reports make a significant contribution to the correct diagnosis and treatment of patients within Healthcare.

The examinations offered to clinicians by the radiology departments are defined as skeleton, chest, mammography’s, ultrasound, odontological, gastrointestinal, examinations performed at primary care units, urinary tract, vascular examinations, CT (computer tomography) and MR (magnetic resonance). The services defined by the name of a part of the body (chest, skeleton) implicitly means X-ray imaging.

The radiology department involves the administrative staff, which is the link between the radiology department and the outside world; radiographers, who are the specialist in image production; radiologists, who are the interventional and diagnostic specialists; and computer technicians, who support all the other actors with regard to computer systems. Radiological work involves distributed actors that carry out activities occasioned by a high degree of unexpected events.

In the radiology department various computer systems are used, such as PACS (picture archiving and communication system), RIS (radiology information system), and HIS (hospital information system). PACS supports the electronic storage, retrieval, distribution, communication, display, and processing of image data. In combination with HIS and RIS it provides a means for managing work associated with radiological examinations.

The medical staff at the clinical wards writes examination requests on paper. Each request includes data such as the patient’s name, the date requesting the examination, the name of the clinician, the type of examination required (e.g. computer tomography, magnetic resonance, angiography, chest examination, ultrasound, mammography, etc.) and the patients symptoms and signs as well as the clinician’s preliminary diagnosis.

5. Cases: News Agency and Healthcare Institution

5.1. The news agency

It is a very busy day in the Media Department of the news agency. A lot of faxes keep arriving from the TV channels in Scandinavia, as well as from various other European countries. The department's largest customer, a weekly magazine, is supposed to get its TV schedules later this day. In addition, the newspapers must have their daily delivery. However, TV information for more than half of the channels is still missing.

The fax machine is ticking. An employee is already busy entering TV information from faxes into a mainframe system. She looks around, and sees that all of her colleagues are quite busy as well. She knows that it is her turn to pick up the faxes now since the others have already done this several times today.

She walks over to the fax machine, takes the two faxes and puts them in shelves. Both faxes are from Channel 8. One of them contains information that is supposed to be included in the schedules that are to be delivered today. She puts this fax directly into the specific space, labeled «to write» in the week-shelf. The other fax contains information concerning future TV programs. She puts that fax in the in-shelf. It will later be moved to the week-shelf when it is time to process it. She goes back to her desk and continues entering TV information from the Sports Channel that she was working on before the last faxes arrived.

One of her colleagues sees that there is a new fax in the week-shelf. One less missing channel, he thinks. He has just finished entering data from Channel Z into the system, and he is looking for more work to do. He takes the Channel Z fax with him and places it in the out-shelf. He marks the coordination form to show that the information for this particular channel is registered in the mainframe system. Then he picks up the fax from Channel 8 in the week-shelf, and returns to his desk and starts entering that information into the system as well. The last faxes he has processed all contained errors in one way or another. He has called three different channels earlier today, and he hopes that this time the faxes are error-free. All these telephone calls take time, and they bore him.

A third colleague is working with a desktop program to make the TV schedule pages ready for printing. She realizes that there is a new fax in the out-shelf, which indicates that some new information is electronically available in the system. She checks the coordination form and confirms that Channel Z has been finalized. If any information from a channel is missing, this is registered on the form as well. The customer's style sheet is open on her computer. She goes into the mainframe system and copies the information into the right place on the style sheet. She does some proofreading during the formatting, and she deletes some words, rewrites some sentences, etc., in order to fit the text into the space available for that particular channel. When she is through, she marks the coordination form.

One of the writers got tired of all the errors he had handled during the day, and went out to get something to drink. While he is gone, his boss comes by and places a piece of paper on his desk. The paper contains some corrections from the Sports Channel. A representative from this channel had called the boss to ask for some last minute changes in their program. When the writer returns after his short break, he sees the paper and starts working on the new changes at once, before he continues the work he was doing before the break. He knows that when corrections come directly to his desk, it is important. He has to make sure that the corrections are implemented.

When all the TV information has arrived, has been entered into the system, and formatted in the desktop program, the schedules are ready for delivery to the customers.

5.2. The radiology department

An employee from the medical department's administrative staff is entering the hallway in the radiology department. There are shelves on the wall to the right, and he places a document in one of the shelves. When an employee from the radiology department's administrative staff passes the shelves 10 minutes later, she glances at the shelf where the document - an examination request form - is visible. She brings the request to the administrative area, and paper in hand she enters an appointment for the patient into the RIS. She places the examination request form in another predefined special shelf visible to the radiographer out in the hallway between the administrative and image-production areas. After a glance at the shelf, the radiographer is triggered to initiate the preparation of the patient, the equipment, and the room for the examination. She carries out the X-ray examination written in the medical request. She adds information into the medical request, to inform other medical staff of her actions. Then she places the light medical request on a table visible to the administrative staff. When an administrative staff sees it, she distributes it to a shelf the diagnostic area.

A radiologist in the diagnostic area has just finished diagnosing a chest examination, he looks at the shelves where the new examination requests are placed and realizes there are more patients to diagnose. He walks over to the shelves, takes the new examination requests and brings them over to the diagnostic workstations. This patient has old X-ray films from an earlier examination; these need to be compared with the images in the PACS. The radiologist stands up and walks over to the lightboard and positions the X-ray films in a row. When diagnosis is accomplished the radiologist dictates the report on a tape. He walks over to the predefined shelves for secretaries, takes the examination request and the tape and puts them in a shelf. A secretary sees that there is a new report to transcribe. She brings the tape and medical request to the administrative area and adds an examination report to the medical request. Thereafter, she returns to the diagnostic area and places the examination request in the shelf predefined for the radiologist who diagnosed the images. The radiologist sees that there is a transcribed report in his shelf. He takes the document and checks it thoroughly and signs off. Then he places it in a predefined shelf for the next day's multidisciplinary conferences, and goes back to the diagnostic workplace by the computer screens. After the images have been diagnosed a second time at the conference, they are put in an "out-shelf", finally, the administrative staff distributes the report including the diagnosis to the medical department.

6. The Shifting Roles of Paper Documents

Both case descriptions illustrate how a paper document change its roles and meanings between e.g. tool, medium, coordinator and trigger of action when placed in different contexts in the radiological institution and in the news agency. This section takes a closer look at the case description from the radiological institution and the news agency in order to identify how the roles are shifting.

Initially, when written request is placed in an in-shelf in the administrative area at the radiological institution, it has a coordinating role in the organization of work[12]. When it is seen by an administrative staff it triggers the administrative staff to register and book a patient. The administrative staff, thereafter, places it in a pile outside the image production area. When a radiographer sees it, the written request has the role of a medium that communicates the overview in work. The written request becomes a tool in the image production work that affords essential information sharing between medical staff. When the examination is carried out, the written request is placed on a table in the diagnostic area, the context is changed, and it has again a coordinating role in the organization of work. When it is seen by radiologists it initiates and triggers a radiologist to diagnose the x-ray images. During the radiologist's diagnostic work is the written request a media for communicating medical information between the medical staff. The written request becomes a tool in the radiologists diagnostic process. Thereafter, it is placed in a predefined shelf for the transcription of reports, having a coordinated role in the organization of work. When the administrative staff transcribe the dictated tapes the written request becomes a tool again. When it thereafter is placed in a shelf visible and seen by radiologists it triggers work again. While the radiologist checks the report it becomes a tool. Thereafter, it is placed in an out-shelf in the entrance of the department, it has a coordinating role in the organization of work. Finally, the written requests become mediums for communication between the requesting units and the radiology department when it is delivered to the requesting unit.

If we look back on the case description from the news agency, we see that the fax-sheets have the same roles as the medical requests have in the radiology department. The TV schedules are mediums for communicating TV information between the TV channels and the Media department. When the fax-sheet arrives at the Media Department and is seen by the workers it initiates or triggers work.

12 For more readings on paper documents coordinating and accumulating role see Berg, M. (1999).

Someone has to act according to arrived fax. When it thereafter is placed in a shelf according to when it has to be retyped, today, next week or later, it has a coordinating role in the organization of work. The fax-sheet becomes a tool in the writers rewriting process. When the writing is done it is again a coordinating artefact important for the employees making the final pages in QuarkXpress. And, the schedule becomes a medium for communication between the TV channels and the TV viewers when it is delivered to the newspapers and magazines.

7. How Documents' Roles are enabled in Different Contexts

In order to understand what written documents do in work practice will we in this section discuss and analyze on what grounds written documents embed different roles and is able to shift between different roles. This section is a more theoretical analyzes of the descriptions of the previous sections.

The fact that paper documents are tangible, ecological flexible and light have implications for the ease of which they can be physically transported within the communities and laid out in particular spaces (Luff et al.,1992); Harper & Sellen, 1995). People tailor their documents in order to differentiate and highlight particular items. As illustrated by Luff et. al (1992), doctors may underline or mark text with colored pens in records to make colleagues aware of irregularities in treatments, and architects sketch in and ring changes to their plans. Regarding documents as ecologically flexible highlights the adaptability of documents' properties to a range of situations and contingencies. A doctor can examine a patient and glance at the record at the same time (Ibid.). Paper documents have many more properties, for instance the feature of being stable, external and therefore potentially available to people across time and space (Levy, 1994; 1988).

In the analysis of our cases we have seen that different properties are made use of in various settings. Furthermore, we have seen that as the context change, some properties becomes more essential and central while others become less necessary and peripheral. For instance, when a fax-sheet or a written request is used as a tool and medium an important property of the documents are that they consist of information (represented as structured text) and that this information is shareable across time and space in the media department as well as in the hospital. The fact that written requests are tangible is most often of less importance in the diagnosis of x-rays. Just as the fact that fax sheets are tangible and light is most often of less importance in the rewriting of fax-sheets. Contrary, in cases where the fax sheets and written requests have a role as coordinators the information sharing aspect is not as important as the properties of being light, visible, and tangible, because this supports the distribution and placement of paper documents at tables, in shelves etc. The same is true for the situations where documents have an initiating or triggering role. The documents' properties do not alone define the documents' role, but it enables or restricts the variations of its use.

It is illustrated in this paper that what also enabled the paper document's roles were the way it was linked to many other artefacts, such as, shelves and tables, and connected people e.g. secretaries, radiographers, radiologists, writers, and administrative staff managing and supporting it. Over time, various artefacts are introduced into the work practices to help organizing work. Shelves are introduced to organize paper documents and make it easier to sort them according to given criteria. During time, the interactions between artefacts and humans become institutionalized and conventions and routines get established. For instance, conventions such as the paper order must be placed on a particular table in the hallway, in order to communicate to the radiographer that a patient is waiting to be examined. In this case, the placement of the written request connects the administrative activity with the image production activity. Just as the predefined placement of paper documents in the in-shelf, week-shelf or out-shelf connects different activities in the news agency. All these artefacts, humans, conventions, routines, skills and knowledge are factors that have impact on the use and roles of documents in work practices at the radiological institution and the news agency.

8. Artefacts in Work Practices

We have observed that humans and artefacts are interrelated in work in order to fulfill some aims or intentions. Artefacts are developed and brought into our world to support us in our work. And, we are more or less dependent on them in that respect. If we look around in our work places we see documents, binders, computers, telephones, fax machines, printers, shelves, pens, cups, etc that we use and interact with every day. At other work places hammers, nails and screwdriver or shots, stethoscope and tweezers are present. However, these artefacts are, in some respect, "parts of us" (Ehn, 1988), and we cannot do our job without them.

All these artefacts have intentions, properties and features that are more or less generally accepted. For instance, the aim of shelves is to support the organization of work by sorting documents, or other artefacts, in them. The hammer is used to nail. And, documents are produced and used for the need of sharing information. However, artefacts may have more peripheral properties as well, and these peripheral properties may become important common resources that the communities of practice rely on.

The "tool perspective" and the "medium perspective" in system design is not sufficient in the understanding of a network, because an artefact may have other roles as well. According to the medical request the 'tool perspective' and 'medium perspective' supports the diagnostic work and the information sharing aspects respectively. In general, these roles are the central ones of a medical request. However, as we have illustrated in our cases, do the paper document have many more roles as it translates between various contextual settings in the radiological institution as well as in the news agency.

In a way, artefacts may be active actors as well. For instance, as we described above, the administrative staff at the radiology department receives an examination request from a clinician, the administrative staff places the examination request in a special shelf visible to the radiographer. After a glance at the shelf, the radiographer fetches the request and reads the information. She then carries out the X-ray examination requested in the document, etc. The similar observations have been made at the news agency. We have observed that, in these situations, artefacts, such as documents on shelves, trigger human action. When and if documents are placed in specific locations, they represent signals. The same is observed at the news agency. What happens on the fax machine, the number of faxes received, and the shelves in which they are placed, are of vital importance to how the working day will develop.

In addition, Dourish and Bellotti (1992) emphasized the importance of awareness in work, and we illustrate how this awareness may depend on the arrangement of artefacts in work practices, i.e. documents in shelves or on tables.

Latour (1987) and Akrich (1992) state that artefacts have politics, in the sense that «they constitute active elements in the organization of the relationships of people to each other and with their environment» (ibid. pp. 1). This does not only mean that they are active in the sense that they are necessary, but also, as we have seen, active in a way that they coordinate, and even trigger or initiate, work.

The perspective of saying that artefacts as well as humans can be actors, in the sense that they put other humans or artefacts into actions is an analytical stance, and not an ethical position (Law, 1992). We, as well as Law (1992), do not mean that we have to, or should, treat people as machines. We do not want machines to have rights, duties or responsibilities that we usually accord to people. An artefact cannot take control over humans literary speaking. The point we want to make, however, is that artefacts may have peripheral properties that enable various use within a community of practice, and that conventions in work “allow” artefacts to have the role as actors. We have in our cases illustrated that paper documents were actors that triggered work; they made things happen and were in a way “subjects” that people relied on. Therefore, in order to understand work practices, we must see artefacts as actors as well as tools and media.

9. The combination of perspectives

An aim with this paper was not only to illustrate and analyze how documents embed various roles in settings, but also to describe and be more specific of how the actor network theory perspective in combination with the borderline issues perspective have supported us to describe and understand the arrangement and reproduction of people and technologies in networks in one way. Through the

ANT perspective we have focused on how everything is connected to everything in the radiological institution as well as in the news agency. In our studies of connected people and technologies in different contexts we have illustrated how an artefact such as the paper document have many roles in a work practice. Some roles are more visible and obvious than others. We have, for instance highlighted the paper documents more obvious role as a tool, supporting the sharing of information. Through the use of the borderline issues perspective we have emphasized to also consider how other more peripheral roles in addition to the more obvious ones. In this way it has become clear to us that there are more roles than the role as a tool, that are essential in order to keep the work practice together. Both perspectives illustrates how different roles are evolved by means of its properties, while the actor-network perspective in addition also stress how other linked artefacts, people, conventions etc. also support the evolvement of different roles in various contexts. We also found that “Borderline Issues” supported us to identify both central and peripheral properties of artefacts, while ANT support us in identifying these properties according to a context. In summary, through the combination of these perspectives can we both see how the roles of an artefact shifts in different contexts, but also see on what grounds these roles evolve. In addition, do the combination of these perspectives allow the understanding and description of how a prior peripheral role of an artefact can become the central one in other surroundings.

In design, documents are often regarded as structured information only and their additional roles are not necessary taken into account (Sandahl, 1999). And, documents are regarded as tools or mediums according to the work situations need for documenting and sharing information (Ibid.). When the paper document has been translated to an electronic document these central roles are inscribed into the computer system. Translating the information in a paper document to an electronic document does not mean that the paper document fulfill all the roles that it has evolved within the network, which may force breakdowns in work situations. For instance, when documents become electronic, there is no need for shelves, tables or fax machines. The visible paper documents are gone, the process of carrying them, sorting them or using them becomes invisible as well. Implicit information necessary for peoples’ awareness is gone. In the words of ANT, we got an unstable actor-network, because the actors that keep it together are removed.

10. Conclusion

We have in our cases illustrated examples of *how* paper documents have different roles in different contexts e.g. we have seen that artefacts have been actors that triggered human activity, we have also seen that the visibility of artefacts, as well as their arrangements, is important for people’s awareness and coordination in work. Some of these roles are central and some peripheral, where the importance of peripheral roles often is unnoticed for outsiders.

We have seen that different properties are made use of in various settings, and that as the context change, some properties becomes more central while others become more peripheral. For instance, when the paper document is used as a tool and medium an important property of the document is that it consists of information and that this information is sharable across time and space. Contrary, in cases where the paper documents has a role as a coordinator the information sharing aspect is not as important as the properties of being light, visible and tangible, because this supports the distribution and placement of paper documents at tables, in shelves etc. The same is true for the situations where documents have an initiating or triggering role etc. These roles of paper documents are important to consider for practitioners in the design of electronic documents not just in news agencies or Healthcare but for any organization in which there is a translation from paper documents to electronic documents.

We have also illustrated that the document's properties do not alone define the document's role, but it enables or restricts the variations of its use. It is not only documents and its properties that enabled its roles it was also the way it was linked to many other artefacts, such as, shelves and tables, and conventions in work as well as connected people e.g. secretaries, radiographers, radiologists, and administrative staff managing and supporting it. All these reasons together, and more, support the different roles played by the paper document in the radiological institution and the news agency. We found that the Actor network perspective support our understanding of how everything is connected to everything in a socio-technical network. While we found that the borderline issues perspective support our understanding of more peripheral and unnoticed roles. Both perspectives illustrates how different roles are evolved by means of its properties, understanding and identifying properties in this sense is important because it illustrates how the artefact's properties are significant for its application. The combined approach of these theories enables us to identify both central and peripheral properties of artefacts, according to various contexts. In summary, through the combination of these perspectives can we both see how the roles of an artefact shifts in different contexts, but also see on what grounds these roles evolve.

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Paper Four

Designing Work Oriented Infrastructures

Ole Hanseth and Nina Lundberg

Abstract

Globally Healthcare is making huge investments in information systems i.e. Picture Archiving and Communication Systems (PACS) and Radiological Information Systems (RIS). Implementing such systems in the hospitals has been problematic, the number of systems in regular use is low, and where the systems are in use the benefits gained are far below what has been expected. This paper analyzes and identifies a number of challenges one will be confronted with when implementing PACS and RIS. To deal with these problems it is suggested to consider them as a "*work oriented infrastructure*". This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. These are, and should be, designed and implemented primarily by their users based on their actual use of the technology.

Keywords: Artefacts, Information Infrastructure, Gateways, Work Practice, Healthcare.

1. Introduction

The introduction of IT into (large) hospitals has been slow and problematic. Electronic Patient Records (EPRs) have been developed since the sixties but are still not well represented – at least in large hospitals (Berg 1999). The state of affairs among general practitioners, however, is the opposite. In Norway, for instance, close to 100% of them are using EPRs. The idea of Picture Archiving and Communication Systems (PACS) is also fairly old. The role of these systems is to store and give access to the different kinds of patient related medical images like X-ray, MRI, CT, ultrasound, etc. And just as in the EPR case, implementing such systems in the hospitals has been problematic, the number of systems in regular use is still rather low, and where the systems are in use the benefits gained are far below what has been expected (Bryan et al. 1998, Peissl, Tellioglu & Wild 1996, Lundberg 1999). The aim of this article is to get a better understanding of the challenges one will be confronted with when implementing PACS systems and how to deal with them. We also believe that our insight is valid for larger groups of complex information systems and infrastructures. The paper is based on the hypothesis that the high rate of failures among projects aiming at the introduction of PACS into radiology departments (just like EPRs) is due to the variety, richness, and complexity of work practices inside hospitals and the interdependencies between all artefacts and technologies supporting them. The complexity of and interdependencies between medical practices and technologies are increasing as medical knowledge increases and new medical technologies are introduced. The high rate of failures among projects aiming at the introduction of PACS into radiology departments (just like EPRs) is also due to the fact that the systems to be introduced as well as existing technologies are seen as separate and independent rather than as parts of complex overlapping infrastructures.

Considering the information systems as well as other technologies in use as integrated into infrastructures gives us new tools and strategies for implementing new systems. First of all, we might learn from the implementation of other infrastructures like railroad, power, and telecommunication networks. But we want, in this paper, to move beyond the characteristics of such "classic" infrastructures. A careful analysis of the infrastructures used within hospitals will teach us, we believe, lessons which will be useful in the development and deployment of new technology. We also believe that these lessons will be helpful in the development of a larger class of infrastructures. We call this class *work oriented infrastructures*. This term is supposed to draw our attention to the fact that such infrastructures are developed to support specific work tasks and practices as opposed to the simple and universal services provided by traditional infrastructures like those mentioned above (i.e electric power at a certain voltage, access to telephone networks, water in a pipe, etc.)

The study is based on the ethnographic method (Hughes et al. 1994), which has lately become widely recognized within the IS and CSCW fields (Suchman 1991, Bellotti and Bly 1996, Button and Sherrock 1997, Button and Harper 1996, Bowers et al 1995). When using this research approach the focus is on investigations and understandings of actual work practice in the particular context. The empirical fieldwork was initiated in October 1996, at one radiology department using PACS. Several different qualitative research methods were used: workplace video studies; interviews articulated by the illustration of video documentation; unstructured interviews; observations and an integration of discussions-interviews and observations of diagnostic practice and social interaction. More than 40 hours of video documentation were conducted, more than 45 hours of observations and 22 interviews were conducted, each about an hour and a half in length. Some participants were interviewed several times.

2. Information infrastructures

In order to improve our understanding of how different artefacts and different technologies are linked together we will look at collections of artefacts as (information) infrastructures (see e.g. Star & Ruhleder 1994, Hanseth 1996, Monteiro & Hanseth 1995). We do not see an infrastructure as some kind of purified technology, but rather in a perspective where the technology cannot be separated from social and other non-technological elements, i.e. as an actor-network (see e.g., Callon 1986, Latour 1987, Akrich 1992 and Law 1992).

When approaching information infrastructures we focus on four aspects. Infrastructures are *shared resources* for a community; the different components of an infrastructure are integrated through *standardized* interfaces; they are *open* in the sense that there in no strict limits between what is included in the infrastructure and what is not, and for who can use it and for which purpose or function e.g. the internet; and they are *heterogeneous*, consisting of different kinds of components – human as well as technological.

An infrastructure emerges as a *shared* resource between heterogeneous groups of users. This is opposed to artefacts of which each user has its own private copy, which each user can use independently e.g. microsoft word, excel, etc. This distinction can be illustrated by the difference between word processors and the Internet's e-mail infrastructure. Each user using a word processor has its own copy and one user's use of her system does not interfere with others'. The e-mail infrastructure of the Internet, however, is one resource shared by all its users. All e-mails are transferred through the same network (although not necessarily exactly the same nodes). And how one user uses the infrastructure may affect others. If one user sends an incredible amount of information, this might jam the network and cause problems for all.

The different parts of an infrastructure are often acquired by individual and independent actors. To make the overall infrastructure work, they must fit together. Accordingly, *standardized* interfaces between components are crucial for making infrastructures.

Infrastructures are *open* in the sense that there are no limits for how many users, computer systems, other technical components etc. that can be linked to it. Infrastructures are heterogeneous socio-technical networks, including many networks in which both technical and social actors take part. The Internet, for instance, is composed of several sub-infrastructures: The global TCP/IP network, and the e-mail, news, and Web infrastructures. These networks can partly be seen as separate and individual infrastructures. However, lots of new infrastructures, for instance infrastructures supporting electronic commerce, are built on top of and integrating these different sub-infrastructures of the Internet. This makes infrastructures heterogeneous as they are built of different kinds of components and sub-infrastructures. But they are also heterogeneous in the sense that they include non-technological elements. For instance, Internet includes the work of large numbers of support personnel. Without them the Internet would not work, it would not exist as the Internet. Accordingly we see infrastructures as socio-technical webs, as actor-networks.

3. Radiological work practices and infrastructures

We will in this section describe the work practices within the radiology department and practices within the clinical departments regarding their collaboration with the radiology department. Based on this we will also describe the technologies used – physical artefacts as well as computer systems – and how they are linked together into infrastructures.

3.1. Work practices

The work practices described are those we have observed at the Thoracic section at the Radiology department at Sahlgrenska Hospital in Gothenburg, Sweden. We will describe the services delivered to and the communication and interaction with its ”customers” as well as the activities going on inside the section.

3.2. The interaction between the radiology department and its ”customers”

The radiology department is a service unit for clinical departments inside the hospital, other hospitals, and primary care units (general practitioners). The services delivered are radiological examinations and reports. The reports are based on X-ray and other types of radiological images. Radiological services are important ”tools” for patient treatment and intervention.

The different types of radiological examinations offered by the radiology department are categorized as skeleton, chest, mammography, ultrasound, odontological, gastrointestinal, examinations performed at intensive care units, urinary tract, vascular examinations, CT and MR. The services defined by the name of a part of the body (chest, skeleton) implicitly means radiological imaging. To order an examination the ”customers” (clinical wards, outpatient clinics, primary care units, etc.) send a paper form, a request - or order, to the radiology department. The order identifies the patient and specifies the examination required, the ordering customer (ward, physician), relevant medical information about the patient, and her demographic data.

When the examination is completed, a report is sent to the ordering unit. The report is just the original physical paper order with additional information specified by the radiology department. The following information is included (figure 1): I) the patient name, address and other demographic data, II) confirmation of the scheduling with the referral hospital, III) patient history – clinical information given by referring physician, IV) referring physician's request of choice of procedure, V) multiple notations of the radiographers involved in the examination: examination room used, signature of radiography and contrast medium given, VI) preliminary evaluation by the radiologist who did the examination, VII) priority as decided and signed by radiologists, VIII) final report signed by radiologist.

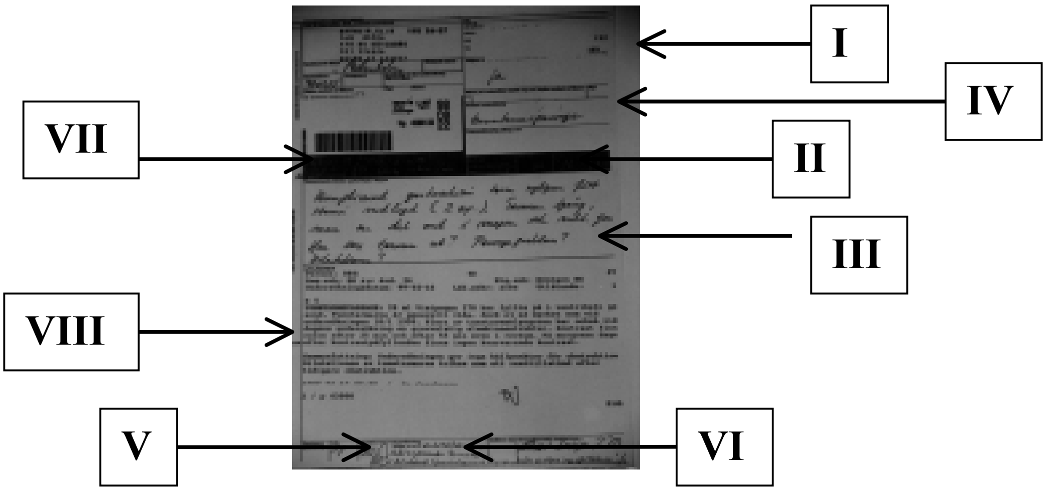

Fig. 1. A radiological examination request/report.

In about 10% of the cases the ordering units specify that the (relevant) images taken should be sent together with the report. Occasionally clinicians request the images after having received the report.

Clinicians often need more information and help from radiologists than what can be specified in the report. To deal with such cases formal meetings where radiologists meet a group of clinicians from one or more medical specialties take place on a regular basis. At the section we have studied there are about nine daily interdisciplinary meetings, called 'ward-rounds,' and three by-weekly ones. In addition, clinicians often calls radiologists to discuss a patient diagnoses or to get advise while patient treatment is in progress. Sometimes clinicians also approach radiologists in person to discuss a particular patient's diagnosis and condition.

In most acute cases ad-hoc groups of radiologists and other specialists (surgeons, internists, cardiologists, anesthesiologists, etc.) are established. These temporarily teams are composed of members of specific medical specialties according to the needs of the patient. The teams are dissolved when patients have been diagnosed and treated.

3.3. Inside the radiology department

The work inside the thoracic section of the radiology department is based on both PACS and RIS[13] (radiological information systems). A gateway is developed enabling the clinician to get access to images in the PACS archive through the hospital intranet.

13 RIS is mainly used for administrative purposes, includes functions for communicating and managing patient data, managing patient registration, scheduling radiological examinations as well as creating statistics used for accounting.

The team designing the PACS consisted of a senior radiologist as project leader and three computer technicians. In addition, students from the departments of informatics and computer science have been working in the project for periods ranging from half a year to one year, focusing on the design of the PACS and various gateways linking the system to its environment.

Due to the fact that a senior radiologist has been in charge of the project there has been a strong focus on existing work practice within the radiology department.

The image production applications have been purchased from different retailers. The computer technicians have done the modeling and programming of the gateways between various image production applications and the PACS in close collaboration with the project leader. The graphical interfaces was specified by the project leader on the basis of discussions with the computer technicians, taking cautious consideration of the heterogeneous work practices in the radiology department.

In the normal (i.e. non-acute) cases the radiological reports are brought to the requesting clinical departments by transporters. The primary task of transporters is to bring bed-bound patients from one department to another. When moving between departments they also bring with them other goods like orders and reports, medical records, etc. The transporters put the reports on a table in the administrative area within the clinical departments. Occasionally the patients themselves, parents to patients, or the ordinary postal service are used to bring the documents from clinical wards, private clinicians, primary care units, and other hospitals.

The activities in the radiology department related to an examination start when a radiological request form is received. The examination is booked and scheduled by assigning a room and a radiographer or a radiologist. The receptionist uses the RIS to check whether the patient has been examined at the department previously, and he checks the details of the patient's demographic data, e.g. name, address, date of birth, and telephone number. If there are any prior examinations that seem relevant, he requests the films from these examinations from the file-room.

The order form is put into a binder notebook. All requests for examinations are stored in such binder notebooks until the day the examination is taking place. The binders are stored in shelves in the administrative area. They are organized according to examination type and date. A glance at the shelves gives an overview of the scheduled workload for the present week.

The radiographers walk to the shelves to find out whether there are any patients to be examined and to collect the order forms and x-ray envelopes. The patient registers herself in the reception area when arriving at the examination day. She is thereafter directed to a dressing room and/or a laboratory.

Before the examination starts the receptionist has placed prior film (i.e. non-digital) images, in case there are any, in a trolley in the diagnostic area which is easily available for the radiologists when interpreting the new images.

The radiographer performs the examination and verifies that the images are of acceptable quality. The images are then stored in the PACS and administrative personnel bring the order form to the diagnostic area. The request form is put on a table located in the area between the corridor and the image interpretation area.

Fig. 2. A radiologist diagnosing PACS images on workstations.

At the thoracic section, there are usually five to six radiologists being assigned to the interpretation of the images every day. This is, however, only one of several tasks they are doing (others include regular meetings, answering ad-hoc requests from clinicians, participating in multidisciplinary teams in acute cases, etc). Radiological work – like the work of clinicians – is not office work. They work in meeting rooms (like those especially designed for 'ward rounds'), in the image interpretation area, in the imaging labs, etc. A large part of the work is, in fact, done while moving around in the corridors and other shared open spaces between different rooms having specific functions. While walking up and down the corridor outside the image interpretation area, the radiologists can see how big the pile of orders on the table is. The radiologist fetches the paper orders from the table and sits down at one of the computer screens being connected to the PACS. With the paper order at hand she checks whether there are any relevant film images from earlier examinations. If so, these need to be compared with the images in the PACS. She will then fetch the films from the trolley and position them in a row at the light board being located next to the computer screen. Sometimes the radiologist uses the telephone to request additional images from the archive. She returns to the workstation and scans the barcode to get an overview of the patient's previous radiological examinations. The PACS and RIS are integrated into one shared user interface. Information about previous examinations as well as their examination dates is found in the RIS system while images are found in the PACS. The images are presented in two rows below the RIS information (5 x 5 cm per image). The images just taken, and possibly images from earlier examinations which are stored in the PACS, are presented on two computer screens for detailed examinations. The radiologist reads and compares the images to complete the diagnosis.

The radiologist enters the reports, when short, directly into the RIS. The radiologist thereafter prints the report on a laser printer and puts it into a paper envelope together with the paper order and thereafter she places it on an 'out-shelf' for the requesting unit. In case of long diagnostic reports the radiologists dictate their reports to typists who later on register the information in the RIS system. The typists then prints the written report on paper and puts it into the radiologists' personal shelves. The reports are checked and signed off by the radiologists and placed in an 'out-shelf.'

If the ordering unit has specified on the order that they want copies of the images, analog film images are produced from the PACS on a laser printer and put into a folder together with the report.

In the normal cases the reports are picked up in the out-shelves in the radiology department by transporters and brought to the ordering departments. The transporters put the reports on a table in the administrative area at the clinical departments. The secretaries sort and place the reports in the shelves of individual clinicians. The clinicians collect the reports from their shelves when passing by and read them. They write a summary of each report into the medical record. The clinicians put the medical record accompanied with the radiological report on a table in the administrative area. The secretary brings the medical record to a table in the file room (archive). Archive clerks sort and place the medical records in their proper locations in the shelves (determined by the patients' demographic data). In emergency cases (and complex ones) the clinicians call the patients and inform them about their diagnosis and future treatment. In the non-complicated cases (i.e. out-patients) the diagnostic results may be sent to the patients via mail.

Fig. 3. An interdisciplinary meeting at the radiology department.

At the daily meetings the order forms are placed in a pile on a table and film images are placed on light boards. If needed a trolley with additional films are placed on the floor. A secretary has prepared all this in advance. Additional film images may also be retrieved from the file-room during the meeting if needed. After the meeting secretaries demount the film images and put them in folders accompanying the orders and place the folders in a trolley to be moved to the administrative area. These meetings give medical specialists from different wards a chance to jointly discuss patient diagnosis and treatment.

During the ad hoc conversations (and calls) between radiologists and clinicians, secretaries call the archive and request the images. Archive staff bring film images to the radiology department, and secretaries help the radiologists to arrange the material. In addition, secretaries, sometimes, bring the material to a table in the administrative area. Archive staff fetches, sort and place the material in their proper places in shelves.

In complex cases, ad hoc discussions about further investigations and interventions are required before a diagnosis can be made and patient treatment can proceed.

In the acute cases, radiological staff may receive an alert preparatory phone call from the emergency department or another hospital ward prior to the patient's arrival at the department. The order form is in these cases either faxed or sent with the patient. An ad-hoc group of radiologists and other specialists (surgeons, internists, cardiologists, anesthesiologists, etc.) is established. How such groups are operating depends on the patient condition and the overall workload at the hospital. They often need to develop complex strategies rapidly, and they have to make a number of "innovations". For instance, in a car accident with abdominal trauma the medical staff need to discuss the workup; what diagnostic examination to do; what tests to take; what life support systems needed etc., the staff also need make examination rooms available, which in turn provoke unexpected rearrangements of work context and content. Changes in the patient's condition may at any time change the handling.

3.4. Radiological Infrastructure

We will now turn to the infrastructure supporting the work practices just presented.

3.4.1. The infrastructure supporting the collaboration between the radiology department and its "customers"

The infrastructure, the foundation, supporting the cooperation between the radiologists and their customers includes, first of all, the physical order and the reports (which the order forms are transformed into during the examinations) and the images. We also include in the infrastructure the institutionalized communication forms used: the request/response communication, the daily meetings, and the ad-hoc conversations. This infrastructure is supported by a more general and basic one consisting of transporters, trolleys, shelves, tables, personal callers, phones and fax machines, secretaries, other support staff (medical assistants), etc.

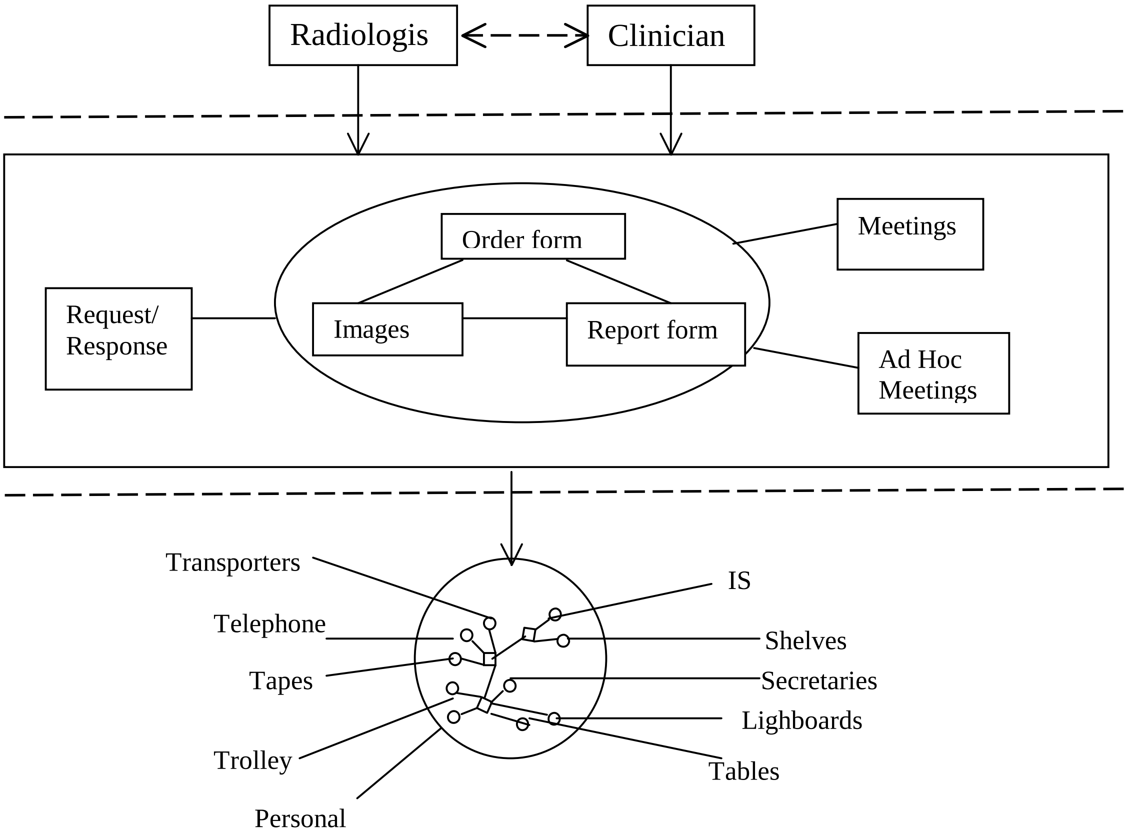

Fig. 4. The radiological information infrastructure

Seeing orders, reports, images, meetings and ad-hoc conversation as infrastructure is in conflict with a narrow, and rather conventional, understanding of infrastructure as just material structures like roads, cables (for telephone or electric power transmission), water pipes, etc. But we want to look at the orders and reports as well as the immaterial phenomena such as meetings and conversations as infrastructure because

- they constitute together the foundation upon which the collaboration and division of labour between radiologists and clinicians rest,
- the different elements are linked together in the sense that each of them is based upon the existence of the others, and the role of each is defined in terms of how this role fits together with and links with the other elements' roles.

This infrastructure is linked to and a part of the infrastructure for collaboration between all departments in a hospital. It is also to a large extent part of a shared infrastructure, foundation, upon which collaboration between all hospitals and other Healthcare organizations are based.

For these reasons the orders, reports, images, meetings and ad-hoc conversations have all the characteristics of an infrastructure, and we accordingly prefer to use this term. It is a shared resource, or foundation, underlying the collaboration inside the hospital just as the Internet is a resource shared by and supporting the cooperation between university students, managers, teenagers, stores, stock markets, banking, associations, medical staff etc.

The ”top level” infrastructure described above (i.e. the one composed of orders, reports, images, etc.) only works as such when there is another layer of infrastructure supporting it. This underlying, supporting, infrastructure is highly heterogeneous. It consists of physical artefacts, more advanced technologies as well as humans. For the orders and reports to work as a shared information infrastructure paper forms must be transmitted between the radiology department and the clinics. Transporters are bringing the forms from the out-shelf in one department to an in-shelf in the other. In other words, the transfer is taken care of by a supporting infrastructure constituted by the combination of transporters and shelves.

In the cases where the patients themselves, parents to the patients or the ordinary postal service are used when communicating with private clinicians, primary care units, and other hospitals these actors are also parts of the infrastructure. In the clinical wards beds, telephones, secretaries, mail services, tables, archives, archive clerks, and shelves are included in the supporting infrastructure.

At the daily interdisciplinary meetings images are retrieved and processed on workstations, order forms are placed in a pile on a table, and film images are placed on light boards. If needed a trolley with additional films is placed on the floor. All this has been prepared in advance by a secretary. This means that the meetings are taking place based on a supporting infrastructure composed of a table, light boards, trolleys, and secretaries.

During the ad hoc conversations between radiologists and clinicians radiologists often call secretaries or other clerical staff and ask them to collect films from the archive. In such cases secretaries, clerical staff, the archive, phones, etc. are included in the supporting infrastructure. In total the transporters, secretaries, clerical staff, telephones, shelves, tables, and trolleys constitute a shared infrastructure supporting the collaboration around patients between radiologists and clinicians. Just like the infrastructure consisting of orders, reports, meetings, and ad-hoc conversations is also open in the sense that it is supporting a wider range of collaborative activities inside the hospital (partly by being a part of a larger infrastructures of equal components).

3.4.2. The infrastructure inside the radiology department

The request form plays a crucial role as a shared infrastructure for the personnel working inside the radiology department. It helps coordinating and keeping track of all main activities. All groups in the department use the order form in various ways in their work. For instance, radiologists use it when diagnosing patients, radiographers use it when performing the examination, receptionists use it when booking an examination, secretaries use it when transcribing the radiologists' reports, etc. The order is a shared resource used by all these groups. But it also coordinates the different activities they are carrying out. This coordination partly takes place by using the order as a medium for representing and storing information. One person writes information on it, later in the process others use this information when determining what to do and how. For each step in the radiological examination process, information is recorded on the order form. This means that the order form during the examination process also becomes a documentation of what has actually been done. This documentation can after the examination is finished, be used for lots of different purposes: quality control, statistics, proving what happened if the patient sues the hospital for mistreatment, etc.

The order form also coordinates the activities at the department not only as a medium representing information, but also by means of its physical features (for an analysis of these features, see Lundberg and Sandahl 1999). In particular, the simple fact that the order form is one single physical object plays a crucial role. The chain of steps are coordinated as the person carrying out one step puts the order on a predetermined location when the task is finished. The one carrying out the next step in the process will then find the order in this position and then do her task. Locations where the orders are placed include binders put into shelves, tables, and mailboxes. For instance, after the examination has been performed the administrative staff at the radiology department places the examination order on a table in the diagnostic area visible to the radiologist. Usually there will be a pile of orders on the table, and the new ones are put on the top. When the radiologists are walking down the corridor, just a short glance at the table will give him an overview of the image interpretation work to be done. The visibility of the paper pile at the table triggers the radiologist to take action. This example also illustrates how coordination is based on the interplay between different artefacts – the order and the table. And similarly, shelves, tables and mailboxes are more than storage's of documents. They also inform receivers about progress and status in various production processes.

The collaboration within the radiology department is based on an underlying supporting infrastructure. For instance, in order to ”communicate” the order form between the reception area, the image production area, the diagnostic area, and the administrative area secretaries, tables, shelves, trolleys, etc. are used as a supporting infrastructure. Similarly, during the diagnosis of patients, radiologists fetch documents from tables and films from trolleys, they position films on light boards, use the telephone to request additional films from the archive, use barcodes to scan patient demographic data. Accordingly, shelves, tables, trolleys, light boards, phones, archive staff and the archive are included in the supporting infrastructure.

3.4.3. Links and interdependencies

The artefacts mentioned above that are involved in the coordination of radiological work are highly interdependent. They are not just individual tools, they are partly a shared infrastructure in itself, but first of all they are linked to others so that they together constitute the infrastructure that all radiological work depends upon.

The shelves, binders, folders, tables, mailboxes are all designed to fit the paper order form. In the same way are light boards, trolleys, and archiving shelves designed to fit the radiological images. The order is designed to fit the needs of all departments concerning communication routines. The tasks of secretaries and other administrative staff at the radiology and clinical departments are all designed to fit the communication needs. But they are also shaped by the fact that this communication is based upon the paper order form. The other artefacts used in the communication also shape the tasks: folders, tables, and mailboxes. The same is true for the transporters.

The components constructing the radiological information infrastructure described in this paper are not unique for or isolated to radiological communication. The radiological infrastructure is also a part of a large and open infrastructure for the whole hospital, and even a shared infrastructure for communication between all Healthcare units.

Inside the hospital there are several service departments in addition to the radiology department. This includes clinical-chemical and other (microbiology, laboratories, pathology department, blood bank, etc.) Services from all these departments are ordered in the same way. Similarly, hospitals send patients between and order services from each other. Accordingly, the way these services are ordered need to be standardized and the infrastructure used needs to be shared.

3.5. Convergence between information artefacts and clinical practice

Above we have described how infrastructures emerge as artefacts are linked together into long chains. To work properly, the artefacts in the chain must interact. Further, the chain of artefacts is linked together with the working practices of the personnel at the departments. The artefacts are linked together with the working practices of those using the infrastructure in their work, like the radiologists and the clinicians. The chain of artefacts is also linked together with the working practices of the support personnel being a part of the clinicians and radiologists infrastructure, i.e. the secretaries and administrative staff and the transporters. Their task is to bring the orders from one temporary ”storage” (tables, folders, mailboxes) to another. Further, the structure of the order and the rules for what kind of information that should be documented in it, shapes how the specific tasks are carried out (Latour 1987, Berg 1997, Bowker 1997).

The different tasks being a part of the chain of activities related through the diagnostics and treatment of one patient are linked together and adapted to each other to make the overall process smooth and efficient. Similarly, the work practices are linked more indirectly because clinical departments need to communicate and collaborate with all service departments according to the same procedures to operate smoothly and efficiently, in the same way as all service departments want to follow the same procedures in their communication and collaboration with all clinical departments being their customers. Together this means that the work practices at hospitals are linked together into large (socio-technical) networks. In total, artefacts and humans are linked together into a socio-technical web, an actor-network. And infrastructures and working practices are further linked into larger networks. For the hospital to work smoothly and efficiently all elements must be aligned with each other, all networks of networks must be aligned and convergent. Both infrastructures and practices are standardized and institutionalized (Hanseth and Monteiro 1998).

Infrastructures change over time. But due to their size and complexity, the whole infrastructure cannot be changed instantly. It changes as some of its parts changes so that the new still is aligned with the overall infrastructure. The same is the case for working practices. This means that infrastructures and working practices co-evolve slowly over long time, an evolutionary process through a series of small steps. This pattern is the standard change process for infrastructures. Over time, it results in a ”deep ecological penetration” (Joerges 1988, pp. 29-30) i.e. the infrastructures are deeply embedded into practices. The infrastructures are strongly adapted to the practices at the same time as the practices themselves are shaped in a way making them heavily dependent on the infrastructures and artefacts.

Larger changes are invisible as they are not planned as such. That means that all links and interdependencies between separate artefacts and between individual as well as collections of artefacts (i.e. infrastructures) are ”hidden” and so are links and interdependencies between practices (Star and Ruhleder 1994).

4. Designing Infrastructures

Based on the analysis of the radiological infrastructures and work practices above, we will now turn towards design of new infrastructures. We will first discuss what we see as the major challenges in infrastructure design in general. Later on we will address how we can deal with these challenges in the design and organizational implementation of electronic infrastructures supporting radiological work.

4.1. Challenges for Design of Information Infrastructures

4.1.1 Standards

If large networks, and large networks of networks, are going to operate smoothly, they must be convergent and aligned. In technical terms this means standardized. Communication must take place according to shared, standardized protocols. Work must follow standardized practices. Conventions and rules, such as the fact that the paper order form must be placed on a particular table in order to communicate to the radiologist that there is a patient to be diagnosed, are examples of such standardized protocols. In this case, the placement of paper orders connects one activity with another activity just as the placement of paper order in other predefined shelves connect the radiological network with networks outside the radiology department. A requirement of an infrastructure is that everyone follows the same standard. In the standardized radiological network actors rely in their actions on other actors following the standards. An example of this is the rules for how different many medical actors should use the order. Secretaries use the orders to book examinations, radiographers to carry out examinations, radiologists to diagnose patients, archive staff to archive documents, clinicians to order radiological examinations and to carry out patient intervention and treatment, etc.

This implies that designing infrastructures means defining standards. This means technical standards in terms of communication protocols and coordination artefacts (Schmidt and Simone 1996), and standard work practices – i.e. designing a large actor-network with standardized interfaces.

Designing such networks is, however, no easy task. One difficulty is related to the fact that infrastructures are open networks, i.e. they are indefinite. The other problem relates to the design of organizational and human components in the networks. Organisations (in terms of acting agents, not formal organizational structures) and humans' activities cannot just be designed. We will here discuss the first issue, which deals specifically with infrastructures.

4.1.2. Momentum and Irreversibility

The larger number of actors communicating, or the larger number of components linked together, the more important standards are. On the other hand, the larger network implementing a standard, the harder it becomes to change the network. This is so for the following reasons: Changing the network means changing the shared standard. The larger a network becomes, the harder it will be to coordinate all actors' actions. For a large network, it will become, in practice, impossible to make all agents switch from one standard to another one at the same time. The large networks communicating using the same standard paper orders and film images cannot be changed instantly. Another example which all of us is in touch with is the ongoing transition of the Internet to a new version of the IP protocol. This has been going on for some years already and it is supposed to take many years still.

Changing a network from one standard to another over a longer period means that different parts of the network are incompatible during that period. Incompatibility means that the network is not aligned – it does not work. However, the degree of compatibility plays an important role. To make a major change will cause a major incompatibility between the existing network and the new. Such an incompatibility causes problems and the intended change will not take place. To succeed establishing a new network a new practice must be established, the new must match the old during the transition period. This implies that the existing structure constrain how the new can be designed.

The more resources linked to the infrastructure the greater the probability of resistance to translations. In Healthcare numerous artefacts have over a long time been linked to the infrastructure. Just consider all the artefacts already surrounding the paper order in our case; typewriters, shelves, tables, printers, pens, dictaphones, computers, archives, telephones etc., and the different ways work practices have been shaped according to all these artefacts, as well as the spaces arranged around them. Other recourses have also been invested in:

knowledge and skills surrounding the paper documents, and the introduction of staff managing the documents: archive staff, administrative staff, medical assistance, etc. The standard for the paper order supports communication and coordination within and between the heterogeneous socio-technical networks and is therefore most important in these socio-technical networks.

To replace the paper order with an electronic version is facing such irreversibility problems. As the paper order links together, in fact, all Healthcare institutions in a country, the transition must take time. During this change there will be incompatibilities and breakdowns because the paper-based network/protocol does not interoperate with the ones based on computers. A successful transition will then require links and some kind of interoperability across these inconsistencies.

4.1.3. Installed base cultivation and gateways

An approach to the management of the change of large networks must take the existing network, the installed base, as its starting point. The whole network can only be changed in a process where smaller parts, sub-networks, are replaced by new ones while at the same time the new sub-network works together with the larger network. The success of such an approach depends on the identification of sub-networks which are, first, small enough to be changed in a coordinated process, second, the sub-networks have so simple interfaces to the larger network that these interfaces between the new and the old can be manageable. The interfaces between two networks will primarily be taken care of in terms of gateways translating between them, or by users being linked to both networks. How this happens in the introduction and use of PACS at the Sahlgrenska University Hospital will be described in the next section.

4.2. The PACS experience

We will now look a bit closer at the introduction and use of the PACS at the thoracic radiology section. This system was developed in an improvisation (Ciborra 1996, Orlikowski 1996) like process, i.e. through a series of versions where each version was in use for a period, and the next one was developed based on the users experiences. Through such a process, a system well adapted to users' needs has been developed. An important characteristic of this version, an important explanation of its success we believe, is the smooth integration between the PACS and the ”system” (or rather: network) based on film images.

The digital system is the primary one internally at the thoracic radiology section. The instruments generating the images are all based on digital technology. This means that when the radiographers are obtaining the images, they are directly stored in the PACS's database. And the radiologists are also using digital equipment when interpreting the images. They are however, using the order on paper form to retrieve the images to be interpreted. This is done by using an electronic bar code reader to read the bar code, generated by the RIS on the order form. Although the digital images are the primary 'tool' for the radiologist's diagnoses of a patient, old analog images are still being used during the comparison of new and old findings. In addition, analog images must be printed when requested by in-house clinicians, or when the patient is admitted to the radiology department from other hospitals or primary care units that do not have PACS. The digital images are then printed from the PACS onto film via laser printers. The new digital and the old film based infrastructure are integrated through the location of light boards and computer screens in the radiologists' image interpretation area, and the printers for printing images.

The systems are also integrated to support the ad hoc discussions between radiologists and clinicians. The analog images are usually fetched by secretaries from trolleys and mounted on a light board beside a computer screen. Often during these discussions, the clinicians want to have the opinion from the radiologist about how a phenomenon (like a cancer tumor) has changed over time. In such a discussion, comparing images taken over a long time is crucial.

The rooms used in the radiological rounds are also equipped to enable the comparison of film and digital images.

After the PACS technology has been in use for a while, both clinicians and radiologists wanted to extend the system with functions enabling the clinicians to access the images from PC's at the clinical departments. As the PACS technology was running on Unix work stations, the software could not just be installed on the PC's. Instead a gateway was developed converting the images to a format readable by Web browsers (or more precisely, by plug-ins to web browsers). This was a simple solution developed by a master degree student within a three-month time span. The gateway enables the clinicians to access the images via the hospital's Intranet.

The PACS implemented at Sahlgrenska University Hospital must be considered as a success. In our view, this success is primarily due to the way its design supports a network of activities that has a fairly clean and simple interface to other such networks and how the PACS technology is well integrated with the technology supporting the other networks.

4.3. Extending the PACS/RIS infrastructure

We will now discuss how the approach outlined above can be applied to the design of an infrastructure for electronic orders at Sahlgrenska University Hospital. Such an infrastructure will have several important advantages as it will speed up the transmission of orders and reports, the secretaries do not have to register the order in the RIS, the orders and reports will be more easily accessible when needed, etc.

The first important issue, then, is to identify the subnetwork to be changed. We can identify four alternatives. The first subnetwork is the radiology department. Then we can extend this by including the secretaries at the clinical departments. This network can be further extended by also including the clinicians, and finally the external units sending patients to the radiology department for examination.

Which alternative to choose depends on the complexity and costs of changing the subnetwork and the complexity and costs of the links to the surrounding networks. We will here briefly discuss the three first alternatives. The first network is of course simplest, but also the one giving least benefits. The interface to surrounding networks will be very simple (based on paper orders). It can be seen as a gateway converting the order/report between paper and digital forms. When the order arrives at the radiology department, a secretary at the reception will register its information. When the examination is finished, a paper report will be written and put in the mailbox to be picked up by a transporter. The gateway in this case is then a human registering the information and printing the report. This solution also needs to provide functions supporting the coordination of the activities inside the radiology department. An alternative solution would be to register the information, but to keep the paper order for the coordination purposes.

One critical issue with this solution is the registration of the order. This has to be error-free. The order is handwritten by a clinician using medical terminology not (always) known by the secretaries. This problem can possibly be solved by also scanning the part of the requisition where the clinician has specified the examination and other relevant medical information about the patient. If the paper order is used for coordination purposes it will also be available so the radiologists can read the clinicians' handwritings.

In the second alternative, the orders will be filled in electronically at the clinical department, either by a doctor or by a secretary based on a doctor's dictated specifications. In this case, the problems related to registration by the secretaries at the radiology department will not appear. If the radiology department wants to, it may still print out the order and use the physical paper as a coordinator. The report will electronically be available (for instance sent by e-mail) to the secretary at the clinical department when the examination and diagnostics work at the radiology department is finished. The secretary will then print the report and put it into the receiving clinician's mailbox just as today when the report is brought to her by the transporter. In this case, the gateway between the two networks, the electronic and the paper based, is the secretary at the clinical department.

The third alternative extends the second by sending the report straight to the receiving clinician. In this case, there will not be a gateway between the networks based on paper and computers respectively. On the other hand, paper based and electronic networks will indirectly be connected as the clinician will use (be connected to) two separate networks – an electronic one when communicating with the radiology department and a paper based one when communicating with the other service departments.

In case some of the other service departments already have introduced a system sending their reports to the clinical departments. If so, the radiology department should adapt their system to the existing one so that the clinician receives the electronic reports from both departments in the same way. This may happen by building a gateway between the requisition system and the existing one so that the clinician receives also the radiological reports in the system they are already using.

The order plays basically two roles – a medium representing information, and a physical artefact used to coordinate multiple activities. The first role can most easily be played by an electronic order. The coordination role it plays due to its physical aspects is harder to take over by a computer. Some cases, however, are not so hard. Radiographers working all day obtaining images may, for instance, be informed about which patient is the next by a sorted 'to-do' list of patients to be examined. But it is harder to design functions informing radiologists about the number of patients whose images are waiting to be interpreted and inform clinicians about the fact that a report has arrived. One could imagine that they could be informed by sending them e-mail. But hospital doctors are not ordinary office workers sitting at their desk using their PC's. They are working in different rooms and locations, which are not their personal working locations. This includes rooms for examinations, meetings, patients, reception areas, discussing with other doctors in the corridors, etc. They are everywhere - except in their offices. The computers they are using are public rather than personal, and they are located in public spaces like the image interpretation and the reception area in the radiology department. This implies that conventional models, metaphors, and tools for computer based communication do not apply.

If the electronic reports should be sent directly to the clinicians and the paper order should not be used to inform the radiologists about the number of images waiting to be interpreted, an electronic system informing the doctors about this while they are walking (running) up and down the corridors would be crucial. Such a system could be a large screen mimicking the table and the pile of orders in the image interpretation area in the radiology department, and a similarly large screen mimicking the mailboxes (and the reports inside them) at the clinical departments. In addition, the system should be linked to the rest of the infrastructure at the clinical department to inform the clinician about the reception of an urgent report. For instance, a message could be sent to the secretary who then would inform the clinician, or a message could automatically be sent to her personal caller.

5. Beyond universal service: work oriented infrastructures

Having argued that the design of information systems for hospitals has a lot to learn from the development of "classical" infrastructures, we will now move one step further trying to identify features of the paper based radiological infrastructure which go beyond those of "classical" infrastructures – features whose "design" can teach us some lessons about the design of electronic radiological infrastructures as well as others. We will argue that the radiological infrastructure described in this article has some features which it has been attributed in order to support specific communities of practice in their work. In this case we are talking about highly complex and specialized practices whose properties are largely hidden for those who are not members of these communities (and who also the members are unconscious about). We call such infrastructures *work oriented infrastructure*s while the “classical” infrastructures can be called “universal service infrastructures” because they are providing universal services to all citizens. The services provided by the latter kind of infrastructures are fairly simple, used by everybody, and equal for all. Power infrastructures deliver 220 (110) voltage current, telecommunication infrastructures give us telephone services so we can call our friends, roads enable us to drive our cars, etc. And the “user needs” are fairly well known to everybody and they have not changed for hundred years. (This picture is changing as far as telecommunication is concerned due to all new services which new digital telecommunication technology opens up for and which the operators want to sell.)

We believe that these differences account for the fact that the different kinds of infrastructures have been designed in different ways and also that the design of new infrastructures of these two kinds requires different design strategies. Classical infrastructures are, and should be designed, primarily by engineers while work oriented infrastructures are, and should be, designed and implemented primarily by their users (and in use). The radiological infrastructure described above is based on (implements) standards. But the infrastructure is not built by implementing a set of standards which are defined by standardization bodies. The infrastructure is built in a piecemeal (bit-by-bit) fashion over a long period – new elements are added to the existing infrastructures and parts are improved or replaced by improved ones. The changes are carried out by the user communities. There are no engineers telling the radiographers and radiologists, for instance, that the images should be stacked on a table and that its height should be used as a medium for communication and coordination. This specific “communication technology” is “designed” by radiographers and radiologists over time as they discover the fact that the paper orders and films they are transferring have features that can be utilized in this way. The aim is to improve technology use through the introduction of new ways of working and new services. Following Brown and Dugid’s (1994) we can describe this as a process where a community of practice assigns meaning to peripheral aspects of the physical artefacts (paper and film). The central attributes of the paper and the films are their role as media for representation of information in forms of written text and images. Peripheral issues, like some physical aspects of the paper and films, are attached shared meanings and turned into borderline issues. Infrastructures are constructed by linking artefacts together and thereby making them interdependent. This happens partly by linking their central issues together, for instance, by assigning orders and films unique identifiers and using them to specify which sets of orders and films that belongs to the same examination. But infrastructures are to a large extent constructed by linking artefacts together by means of their borderline issues. For instance, the coordination and communication between radiographers and radiologists are using both the order (and the films) and a table on which the orders are put. This coordination is utilizing the table not only as a storage paper, but as a storage of paper which can be located “anywhere”, including the border area between the corridor and the area where the radiologists are interpreting the images. A large scale infrastructure emerges as artefacts are linked together and the work of large communities of practice share their meanings.

Transporters’ primary task is to bring patients in bed from one department (or room) to another. Their traffic between departments was later seen as a possible resource to be utilized for other means, and accordingly the transmission of paper documents all over the hospital is “piggy-backing” upon the main service they are delivering.

The radiological infrastructure is designed by its community of practice. We will argue that this is not just an historical accident – it could not have been otherwise. This is so because of the complexity of the working practices involved. To discover, or even understand, the need for improved technological support, one needs close relationship to existing practices, so close that one has to be involved in the practice oneself. However, practitioners can tell engineers about limits of existing technology and their ideas about what improved solutions may look like. Engineers can then design new solutions which the medical personnel again can adopt. This is the traditional understanding of software (technology) development. This approach works pretty well in many cases, but work oriented infrastructure design is beyond its limits. The reason for this is that to design such an infrastructure, the engineers cannot develop solutions for a closed group of users but for more or less the whole Healthcare community. Engineers can design solutions which can support existing practices in a better way, but only to a limited extent. For complex and highly specialized areas like radiology, only those knowing the area can discover improvements. Improved solutions will be discovered in work. Some improvements will take place as reinterpretation of meanings of existing technologies (i.e. using it in differnt ways, for instance additional information could be included in the orders and reports), some as reinterpretation of existing borderline issues or by constructing new ones, and, finally, some improvements will require changes in the technology itself. Work oriented infrastructures will be developed through bricolage (Ciborra 1996) or improvization (Ciborra 1996, Orlikowski 1996) like improvement processes. The difference between improvization in the design, or improvement, of “traditional” (or rather stand-alone) systems like design of the Lotus Notes application that Orlikowskti (1996) describes, is related to the open character of infrastructures. Contrary to the Notes application, they are not used by a closed user group, but rather a large (indefinite) number of connected and overlapping communities of practice. In the collaboration within and between these communities of practice different but overlapping groups of services provided by, or parts of, the infrastructure are utilized. One group of functions or services, or part of the infrastructure, can only be changed in a way that maintains its compatibility with the other groups of functions it overlaps and is connected to.

The fact that large numbers of users are sharing the same piece of technology is usually assumed to imply that this technology should follow one shared universal standard. This argument has certainly some validity. The fact that all computers linked to the Internet is running the TCP/IP protocol demonstrates the power of such an approach. However, defining shared standards supporting the exchange of medical information is a strategy for building work oriented infrastructures that has proved to be very problematic (Hanseth and Monteiro 1997). For more than fifteen years one has tried to work out standards for exchange of chunks of information like lab orders and reports (including radiological orders and reports). The proposals that have been worked out have been extremely complex and accordingly very expensive to implement and use and very hard to change. Existing practices are inscribed into the standards, and their lack of flexibility implies that they make it harder to improve existing practice rather than enabling this (ibid.). These problems seem to be present to very strong degree in the definition and implementation of EDIFACT messages in general (Graham et al. 1996).

Changes in the infrastructure in terms of changing its meaning or borderline resources, i.e. without changing the technological solutions in itself, can, of course, be carried out by the users without involvement of any kinds of experts concerning the technology used. Concerning the radiological infrastructure described above, which is based on artefacts and technologies like paper forms, tables, shelves, etc., the technology is very simple. The users have the required knowledge and capabilities to change it the way they want. We believe this fact to be an important explanation for of the successful development of this infrastructure. Heath and Luff (1992) and Nygren and Henrikson (1992), for instance, document how important the flexibility of paper documents is in the work of medical personnel. Paper documents can, for instance, be moved around and showed to patients whatever positions they are in, physicians can browse through the paper based medical record extremely fast in the search for relevant information, important information can be derived from the thickness of the record and what kind of forms it contains, etc. Further, paper documents are flexible in the sense that whenever needed, physicians can, when it is relevant, put text into the document beyond what the document template specifies. This is important in complex cases. But it is also important because it enables the users to improvize and improve the technology when new needs appear or opportunities are discovered.

We believe this user control of technology is important for the design of work oriented infrastructures in general. Computer technology, however, is far more complex than paper, tables, shelves, etc. However, some computer systems are more flexible and give more space for the users to find new ways of using the technology to improve their work. The Internet technology introduced at Sahlgrenska University Hospital to give clinicians access to images in the PACS demonstrates this. Other hospitals and Healthcare regions are using Internet technology (Web technology and e-mail) more extensively. Their experience clearly shows the potential of this kind of technology concerning innovative and user driven development of improved infrastructures and working practices.

Standardization has, however, played an important role in the development of the paper based radiological infrastructure. The order form, for instance, is in most countries settled as a standard by national standardization bodies. These standards specify the layout of the paper form and what kind of information they should contain. It is important to note, however, that these standards are defined after paper orders have been used extensively. The standardization process is more of a “cleaning up” type which follows a period where the orders have been changed in different ways in different regions or communities. When a new standard for the paper order is defined, it contains the information and structures required in current practices, at the same time as it has the flexibility required by the users. They can change the standard when new needs appear and new possibilities for improving practices are discovered.

6. Conclusion

The objective of this paper has been to get a better understanding of the challenges one will be confronted with when implementing PACS and how to deal with them. It was also illustrated that artefacts in radiological work are highly interdependent. The shelves, binders, folders, tables, mailboxes, typewriters, tape-recorders etc. are all linked to the radiological paper request form. In addition, these artefacts are linked together into long chains. The chain of artefacts is also linked together with the working practices of the personnel, i.e. the radiologists, radiographers, clinicians, secretaries and administrative staff as well as the transporters. Furthermore, the various medical work practices are linked because clinical departments need to communicate with all service departments. Together this means that the work practices at hospitals are linked together into large socio-technical networks.

Infrastructures and work practices change over time. It was illustrated that due to their size and complexity, they cannot be changed instantly. Hence, infrastructures and working practices co-evolve slowly over long time, in an evolutionary process through a series of small steps. It was also concluded that the more resources linked to the analog infrastructure the greater the probability of resistance to transformations. In addition, it was also concluded that the larger the medical network implementing PACS the harder it will be to coordinate the actions of all actors in a change.

It is suggested that the design of PACS and RIS could be improved by considering these systems as *work oriented infrastructures.* This term is supposed to draw our attention to the fact that these systems are developed to support specific work tasks. PACS and RIS as work oriented infrastructures has taught us some lessons about the design of electronic radiological infrastructures. We conclude that these infrastructures are, and should be, designed and implemented primarily by their users based on their actual use of the technology.

It is suggested that one way to improve and make PACS part of a work oriented infrastructure is to link it to other information technologies in use. Shared conventions and rules, i.e. the fact that the paper request form must be placed on a particular place at a table in order to communicate to the radiologist that there is a patient to be diagnosed, are of significant importance for the conduct of medical work. It is of great importance to in a similar way, develop shared conventions and rules related to the use of work oriented infrastructures.

Designing and implementing computer systems as PACS cannot be performed in a “big bang” process. The actor network can only be changed in a process where smaller parts are replaced by new ones bit-by-bit. The old and the new socio-technical networks must be linked through interfaces, these interfaces can be taken care of by gateways, enabling networks with different technical solutions to communicate and interact.

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Paper Five

Standardization Strategies in Practice

- Examples from Healthcare

Nina Lundberg and Ole Hanseth

Abstract

This article explores some of the consequences of strategies used to develop electronic standards in Healthcare, especially the consequences of electronic standards for communication work. The two standardization strategies explored are the prototype strategy used to develop intranet applications and the specification strategy used to develop Picture Archiving and Communication Systems (PACS) in healthcare. It was found that computer systems based on different electronic standards intervene in work in different ways, and that they do not always intervene in the ways in they were initially intended. For example, the PACS based on the DICOM standard have primarily attained a local role, although its initial aim was to support universal image communication within Healthcare. On the other hand the intranet application based on the Internet standards primarily not designed for this particular purpose has come to support communication of images and reports within the heterogeneous hospital network.

Keywords: IS Design, Internet, Standards, PACS, DICOM, Healthcare.

1. Introduction

During the past 15 years, international organizations and countless dedicated individuals have devoted great effort to the development of electronic standards for storage and transmission of radiological images (Jost, 1994). It is impossible to build large communication networks of people and things unless they are based on standards (Hanseth and Monteiro, in manuscript). As there is a great need for communication within Healthcare, the need for standards is obvious. To support this large-scale communication, a number of technical standards have been developed within Healthcare, such as Digital Imaging and Communications in Medicine (DICOM). Between 1983 and 1994 this standard was developed mainly by the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA). It is now also being developed in conjunction with JIRA/IS&C in Japan, and reviewed by IEEE, ASTM, HL7 and ANSI in the USA.

Different strategies are associated with the development of electronic standards. For instance, the European standards for Healthcare, including DICOM, are based on a specification-driven approach, seeking more homogeneous solutions, presupposing a common design implementation in all medical units. Simultaneously, other electronic standards have been implemented in Healthcare, such as the Internet standard. The Internet society has developed through a prototype-oriented strategy and is growing rapidly. It is based on the idea that there would be multiple independent networks of rather arbitrary design. The idea of the Internet was that any provider could freely design an application and make it work together with the other networks in the Internet. It emphasizes an underlying heterogeneous solution in work.

There has been little research focused on electronic standards in Healthcare (Hanseth and Monteiro, in manuscript), although electronic standards are rapidly being introduced. For instance, Laurin (1998) reported that 60 % of all radiology departments in Sweden were planning to introduce electronic standards within the next three years. It thus seems important for us to strive to contribute an understanding of some of the consequences of electronic standards in medical work.

We view standards as an agreement that establishes a framework within which to solve particular problems. An example of this is the rules for how different many medical actors should use the radiology request. Secretaries use the request to book examinations, radiographers to carry out examinations, radiologists to diagnose patients, archive staff to archive documents, clinicians to request radiological examinations and to carry out patient intervention and treatment, etc. The standard covers more than one local activity, and is applied in the context of making things work together over distance and heterogeneous metrics. Although its aim is to support cooperative work, it cannot guarantee interoperability between entities. Communication must take place according to shared, standardized protocols. Work must follow standardized practices. In the standardized radiological network actors rely in their actions on other actors following the standards.

The empirical data has been collected from a larger ethnographic study that was initiated in October 1997 at the Radiology Department, Sahlgrenska University Hospital, Gothenburg, Sweden. It has been followed up by several additional studies at the Pediatric Radiology Department, Astrid Lindgren Children’s Hospital, Stockholm, Sweden and at the Radiology Department, Örebro University Hospital, Sweden. Ethnography has recently become widely recognized in the IS field (Hughes et al., 1994; Bowers et al, 1995; Bellotti and Bly, 1996; Button and Harper, 1996; Button and Shorrock, 1997; Suchman, 1998). The research approach is to investigate and understand the relevant work practice in context. Several different qualitative research methods were used:

workplace video studies; interviews illustrated by video documentation; unstructured interviews; observations; discussions and interviews integrated with observations of diagnostic practice and social interaction. Over 40 hours of video documentation were recorded. Over 45 hours of observations and 28 interviews were conducted, each about an hour and a half in length, with some participants being interviewed more than once over the period of study.

The aim of this research was to explore some of the consequences of different strategies used to develop electronic standards in Healthcare. This was done by analyzing the implementation of different electronic standards, based on various standardization strategies, in work practice.

The remainder of the paper is organized as follows. Section 2 presents the related research. Section 3 describes the electronic standards in Healthcare at the hospitals we have studied. Section 4 presents the use of electronic standards in radiological practice. In Section 5, the use of different standardization strategies are analyzed and discussed. Our conclusions appear in Section 7.

2. Related Research

The importance of standards for overlapping cooperative work between distributed units has produced a range of studies and analyses of standards in socio-technical networks.

Important studies have centered on the design of technical standards. For instance, Hanseth and Monteiro analyzed the ISO (International Organisation for Standardization) and Internet 'association' supporting the creation of standards (Hanseth, 1996; Hanseth and Monteiro, 1996; Hanseth et al. 1996). They conducted a series of investigations into the interplay between stability and change. They highlight the tension between standardization and flexibility in the creation of communication systems as a key design factor.

This approach resembles those applied by Bowker and Star (1994; 1999) and Star and Ruhleder (1996). In their studies they analyze the evolution of the classification of diseases developed by the World Health Organization. They illustrate how the establishment of standards is anything but neutral; they are the results of political and social work.

In this paper we seek to add to the current understanding of implementation and use of different standardization strategies in Healthcare. We analyze and discuss two different standard strategies used to design electronic standards in Healthcare. There are complementary studies to ours; for example, Berg (1997) explores empirically how universal standards, by means of medical records, are appropriated to local medical contexts.

In order to add to the understanding of standardization strategies in Healthcare, in the next section we will briefly describe the different strategies used to develop and implement the PACS (Picture Archiving and Communication Systems) and intranet applications in Healthcare.

3. Electronic Standards in Healthcare

According to Bowker and Star (1999) standards are any set of agreed-upon rules for the production of (textual or material) objects. Legal bodies often enforce standards. There is no natural law that the best standard will win. Once a standard has been adopted by a large number of users, it is very difficult and expensive to change.

An important feature of a technical standard is that it has a social dimension in addition to the technical one. For instance, medical data must be written in a way that medical staff understand - data must be consistent with standardized shared (Latin) concepts. The technical standard itself has limited influence on either the medical data written into it or the way that the medical information is understood and used by medical groups. It is therefore important to develop a social standard for the use of a new technical standard. In practice, these two dimensions of standards are inseparable.

3.1. The DICOM–based on the specification strategy

The CEN/TC 251, which is developing the DICOM standard, has divided up its work into seven different subfields within Healthcare: terminology, semantics and knowledge bases; information modeling and medical records; communication and messages; imaging and multimedia; medical device communication; security, privacy, quality and safety, and intermittently connected devices. DICOM was initially designed as one single universal standard, or one coherent set of standards, covering any need for medical imaging and multimedia exchange. At the outset, it focused on radiological imaging.

The DICOM is based on several service classes: DICOM store, DICOM query, DICOM retrieve, DICOM print, Ethernet and TCP/IP Networking. To claim that one is following the standard one must document and specify what service classes this is related to in a conformance statement. Moreover must one in the conformance statement specify in which way this service class is used. Without a conformance statement, a system does not comply with the standard. The DICOM standard does not specify the overall set of features and functions to be expected from a system. There is a number of compulsory computer attributes that has to be included in the system. There is also a number of volunteer attributes, that the users can choose among themselves. In sum, conformance statements should confirm that all compulsory attributes are included in the system, in addition should all volunteer attributes used be specified as well. It will be specified in what way data is communicated by the service class user (the digital images retrieved from the PACS) and what way the service class provider communicates data (the way digital images is sent out from the PACS database). This means that a valid response to all of the optional data elements must be incorporated in the application to comply with the DICOM standard.

As illustrated, the specification-driven approach seeks a more homogeneous solution, presupposing a common design implementation in all medical units. It is based on the idea that there will be one homogeneous technical network of uniform design. It is designed for one application - PACS. The conformance statements impose stringent restraints. Under these ‘regulations’, DICOM was developed on the assumption that there would be a single universal network for image communication within healthcare.

PACS technology is based on DICOM conformance statements. Its main function is to create a shared electronic unit where radiological images can be saved. PACS facilitate the sharing of the image data across organizational and professional boundaries (Tellioglu and Wagner 1996). Images may be archived and organized in central units, and be accessed and used in cooperation by locally distributed actors.

In 1995, a proposal for the installation of PACS at the Thoracic Section, Radiology Department, Sahlgrenska University Hospital (SU) was put forward and accepted. This proposal was linked with a relocation of the radiology department. The new department was built and equipped by May 1996.

PACS are built around a central archive to which all workstations are connected through fiber distributed data interfaces (ATM/fiber optic network) and a Fast Ethernet. PACS have an interface to the Radiological Information Systems (RIS) that support the transmission of data from these systems to the connected workstations at the radiology department.

Similar implementations were installed in April 1998 at the Pediatric Radiology Department, Astrid Lindgren’s Children’s Hospital (ALB) and at the Radiology Department, Örebro University Hospital. These two sites have implemented the same PACS application. This is a system bought from a vendor.

The vendors offer training in connection with all PACS implementations. In addition, there are radiological ‘superusers’ that support the training of new users.

3.1.1 The PACS implementation process

Various design approaches can be applied in the development of computer systems. The vendor developing the PACS at Astrid Lindgren Children’s Hospital and Örebro Hospital has developed its own design approach. Once a year the vendor meets with all its users from different hospitals in a joint meeting. The aim of these meetings is to specify the requirements of the next PACS version. The meetings start out with a ‘brainstorming session’ in which all users can put forward specifications of new and improved PACS functionalities. The vendor then quotes a price for each specified improvement to the functionality. When all costs have been specified, the vendor states the total amount of money to be spent on the new PACS version. A voting session is started. Users have a number of votes proportional to their investment in the PACS. Specified functionalities will be implemented according to users’ priorities. For example, in last year’s version users gave priority to the ability to illustrate images in a stack. The possibility to tag one or several images in a stack, as well as to swap images in two stacks simultaneously, was also given priority. This is useful, for instance, in a tumor case where there may be about 20 radiological examinations: X-rays, ultrasound, CT, MR, etc., and some 1000 images may be included. Of all the images, there may be about 10 that the radiologist wants to save in a stack. The next radiologist who needs to examine this patient may retrieve the saved stack.

In next year's PACS version, users have specified and given priority to the implementation of pointers between desktop folders. This can eliminate storage of the same image in multiple electronic locations. A copy may currently be saved in 7-10 different desktop folders in the short-term archive, which in turn fills the short-term archive much faster than had been expected.

According to the radiologists, this process of specifying the PACS design is too slow. As one radiologist put it, 'It takes such a long time just to organize these large user meetings. We have ideas, but the vendor has limited scope for making changes - it is a bit difficult. We are used to working with technology and fixing problems ourselves as they arise. With PACS we have to work together with the vendors. We are stuck with them, the PACS and its standard.' He continued, 'The PACS design process does not encourage quick thinking; it is a less dynamic way of working. I do not think this design philosophy will last for long. It just takes too much time.'

The team designing the PACS system at Sahlgrenska consisted of a senior radiologist as project leader and three computer technicians. In addition students from the departments of informatics and computer science have been working in the project for periods ranging from half a year to one year, focusing on the design of the PACS system and various gateways linking the system to its environment.

Due to the fact that a senior radiologist has been in charge of the project there has been a strong focus on existing work practice within the radiology department.

The image production applications have been purchased from different retailers. The computer technicians have done the modeling and programming of the gateways between various image production applications and the PACS system in close collaboration with the project leader. The graphical interfaces was specified by the project leader on the basis of discussions with the computer technicians, taking cautious consideration of the heterogeneous work practices in the radiology department. The system has become a most important and appreciated technology among the radiological users. However, as the system has become larger it has become more and more complex and expensive to create new versions. Several new features are wanted although it has shown to be difficult to both identify technicians that can develop the system and raise financing for the implementation of new features. To overcome the system support problems concerning the PACS database the project leader is planning to hire a company for externally managing this.

According to one of the technologists, the complex structure of the DICOM conformance statements in combination with the size of the PACS is problematic. It requires extensive technical knowledge and finances to redesign, and promotes a development process that is designed in a formal 'specified' fashion. For example, the estimated cost of four lines of code in the PACS was around SKr 180,000. It was related to formal meetings and 'endless negotiations with the vendors', as the radiologist put it. The four lines of code were never implemented. The high cost was due to dependencies between these lines and several other PACS functions that would also have to be changed.

3.2. The Intranet – based on the prototype strategy

The Internet has revolutionized the computer and communication world like nothing before it (Leiner et al, 1997). Since 1985, the Internet has been growing rapidly. The Internet is set to be the underlying basis of new services and products within healthcare, electronic commerce, education etc.

The Internet is based on the idea that there would be multiple independent networks of rather arbitrary design. It is designed for many different applications, such as e-mail, information transfer, remote logins, synchronous communication, disk sharing, and packet-based voice communication. As illustrated, the Internet was not designed for one application alone, but as a network on which new applications could be based. The idea of the Internet was that any provider could freely design an application and make it work together with the other networks in the Internet. It has so far proved remarkably flexible, adaptable and extendable (Hanseth and Monteiro, pp. 84, in manuscript).

In an open-architecture network such as the Internet, the individual networks can be designed separately. Each application can have its own unique interface, which it can offer to users. Each network can be designed in accordance with its specific environment and user requirements. There are generally no constraints on the types of network that can be included or on their geographic scope, although certain pragmatic considerations will dictate what makes sense. In this way the Internet was developed on the assumption that there would be not one single, universal network, but rather any number of heterogeneous network technologies.

After the PACS had been in use for a while at Sahlgrenska Hospital, both clinicians and radiologists wanted to extend the system with functions enabling the clinicians to access the images from PCs at the clinical departments. As the PACS were tailored for complex radiological use and was running on a Unix platform, the software could not simply be installed on the PCs. Instead, an application was tailored to convert the images 'on the fly' to a format readable from the hospital Intranet. This was a simple solution developed by a masters student within three months. It enabled the clinicians at the hospital to access all images at hard-disk level from the PACS at any time from any PC connected to the intranet.

The team that designed this so called intranet one application included students from the Department of Informatics and Computer Science. They have been working in the project for periods ranging from half a year to one year each.

A similar intranet application, referred to as intranet two in this paper, was implemented at the Pediatric Radiology Department, Astrid Lindgren's Children's Hospital, as well as at the radiology Department, Örebro University Hospital.

There is a difference between the two intranet applications. Instead of converting images on the fly, intranet two has developed plug-ins to web browsers, converting both the RIS reports and PACS images to a format readable from the hospital intranet.

News of the implementation of intranet one and two spread through hearsay. The clinicians referred to the electronic access of radiological text and images as a top-priority request. They stressed the need for these images in clinical work, research, and teaching, as well as for explanations for patients.

3.2.1 The intranet implementation process

This section describes how the intranet changed in an evolutionary process as it was implemented in work. As it started to change, the social and technical links associated with the intranet application also started to change.

The intranet application started out as a very simple technology, including the following functionalities: search for a patient; retrieve, zoom and rotate images; display responses from the RIS. It offered access only to the short-term archive (with the 1500 latest examinations). Clinicians used it for research. This meant that clinicians had to collect their images regularly so that they did not lose any data. As a clinician put it, 'If you are away for a few days, the information is lost'. According to the vendors, access was restricted to the short-term archive in order to avoid clashes between queries from radiologists and clinicians.

After the system had been implemented for half a year, the clinicians contacted the vendors. They asked if they could use this intranet application to access the long-term archive. Clinicians also need access to images and requested answers that are more than three months old. Perhaps the intranet application could give them access to the radiological images and texts from home? Could changes to the X-ray images be saved in the short- or long-term archive? Could annotations to the X-ray images, inserted by the radiographers, be retrieved from the intranet applications? As images were sometimes retrieved upside down and there was no way of telling whether it was the right or left part of the body that was displayed on the screen, radiologists requested images to be displayed correctly.

The first request was fulfilled; medical staff can now access X-ray images from both the short- and long-term archive. The second was not: the intranet application could not be used from home, since there was no immediate technical solution that could guarantee compliance with legislation regarding the confidentiality of the X-ray images. The third request was not fulfilled either, since it is not possible to update low-resolution images (such as JPEG images) with high-resolution DICOM images. The fourth request was fulfilled. It is now possible to retrieve annotations that the radiographers have made to the X-ray images. This works well now and has also contributed to the use of the intranet application for diagnostic work – when a radiologist gets a call to his office from a clinician, he retrieves the information for the clinician's patient on the PC and discusses the case over the phone. The final request was fulfilled immediately. It had been possible to mistake a left arm for a right one – there was no way to tell from the X-ray image whether surgery was to be conducted on the right or the left arm. As one of the radiologists put it 'there was no control in the system - causing serious risks for the patient.' For this reason, the intranet application was withdrawn for a few months from early 1999. In spite of these problems, users were very positive towards the intranet application, its benefits in practice and its theoretical potential, which they discussed readily.

The clinicians contacted the vendors again. This time, they asked whether the intranet application could give them access to the scanned paper request sent by the clinician. This was fulfilled; medical staff can now view the clinician's request from the intranet application. This version also included the possibilities to change the brightness and the contrast of the image. This request was not made by this particular radiology department, but most likely came from another user.

With all these improved functionalities, one of the technicians said, 'It is not the functionalities that are the main limitation of this application any more - instead it is the rather slow server that converts DICOM images to a format accessible to the intranet application (JPEG).' However, no user has been rejected access to the intranet application yet. Users are completely free to decide whether, when and how to use this application. There have been very few formal decisions relating to its use.

As a radiologist discussed the potential of the intranet application, he commented: 'I understand why the vendors are scared of this new technology - it enables us to design and develop our own technical solutions. The need for this kind of technology among clinicians is unlimited.' He continued: 'Everyone should have access to this kind of technology - it is obvious.'

As the intranet application started to change, many new actors became central in the design process, for instance, the act relating to the protection of personal privacy, the DICOM standard and the patient. The process also illustrated that when the intranet application started to change, so did its social and technical links. Just as the technology started to change, new application areas were established for the intranet application – surgical work, teaching, diagnostic work, research, etc.

In the next section, we describe the use of the DICOM standard in radiological practice.

4. The Use of Electronic Standards in Radiological Practice

In order to understand the consequences of different standardization strategies, we need to understand how each one of these has become embedded in medical practice. More specifically, we need to know how, for what purpose and in which contexts they are used. This understanding can allow a comparison of the consequences of the two strategies.

The radiology department is mainly a diagnostic service unit, carrying out radiological examinations for clinical departments inside the hospital, other hospitals and primary care units (general practitioners). The radiology department provides interpretations of radiological images and the results are delivered to clinicians by means of reports and meetings. The radiological examinations and reports form a basis for the correct diagnosis and treatment of patients.

The examinations offered to clinicians by the radiology departments are usually classified in relation to the body's organ system, such as the skeleton and chest; mammography; odontological, gastrointestinal, genitourinary and vascular examinations. The classification may also relate to the type of equipment used: ultrasound, CT (computer tomography) and MR (magnetic resonance).

4.1. Medical work practice

In this section we will describe the radiological practice as well as other clinical activities linked to it in radiology departments operating with PACS and intranet applications.

For a radiological examination, patients are usually sent from clinical wards, outpatient clinics, primary care units, etc. to the radiology department. The examination request is created manually by a paper-based system. When the examination request is received in the radiology department, it is scheduled by assigning an examination room and a radiographer or a radiologist to the examination in the RIS. When the patient is scheduled, a message is automatically transferred from the RIS to the PACS. This message triggers the automatic pre-fetching of relevant examinations from the long-term PACS archive after midnight on the night before the patient examination. Retrieval time is kept to a minimum because the next day's images are retrieved during the slack hours of the previous night, and the process does not compete with the archival of new images. The retrieved images are available from the information storage unit, and can be viewed on the screen within a half second to five seconds after the radiologist has clicked on them. Images that are not automatically retrieved must be retrieved from the permanent long-term archives, which usually takes from three to ten minutes, but may take longer if the system is busy. The instruments generating the images are nowadays all based on digital technology. This means that when the radiographers produce the images, they are stored directly in the database of the PACS.

During examination of the patient, the radiographer uses a hand scanner to scan the bar code, which is attached to the paper request. The patient’s electronic request is thereby retrieved on the workstation. She then positions the patient and takes the images. The radiographer views and selects the PACS images, adjusts the density level to produce the optimum image, performs any reorientation and annotation that is necessary, and then verifies the examination. When the images have been verified, PACS automatically transfers the images to a folder, which contains about 1500 examinations for reporting. To diagnose the patient, the radiologist sits down at one of the PACS workstations. All workstations are provided with infrared barcode readers. The radiologist retrieves patient data to the workstations by ”swiping through” a barcoded ID sticker attached to the paper request. When all barcodes have been swiped through, a work list has been created in PACS. With the paper at hand, the radiologist clicks on the first patient in the work list. He reads the patient name and ID in the written request and checks it against the patient data in the electronic request.

Fig 1. Radiologist reading images.

Three monitors are situated side by side. On the left-hand one, PACS and RIS are integrated into one interface, while the middle screen illustrates the new images and the right-hand one illustrates the old images (in this examination) [14]. When the radiologist browses through various new chest images, the corresponding old image will automatically be displayed on the right-hand screen. The radiologist zooms and uses the tools to magnify and change the contrast of images. Manipulating the images on the workstations allows the radiologist to view a range of densities in the image, just as it enables the instant measurement of various findings. He switches between images showing different views of the patient’s chest to compare them. After the diagnosis has been made, the radiologist must decide whether the examination should be brought up on the ward round or not. If so, he must drag and drop the electronic request to the relevant ‘meeting list’.

14 In other examinations it could very well be that old and new images are integrated in the same monitor and interface.

Fig 2. Meeting at the Radiology Department.

At the daily meetings at the radiology department, when the radiologists and clinicians discuss the patient examinations, electronic images are fetched from the meeting list in the PACS. The radiologist zooms and filters the images to highlight findings.

The importance of various kinds of lists as a resource in work was also confirmed at ALB and Örebro Hospital. Not only do they support the organization of work, but also, as a senior radiologist put it, they make it possible to work in new ways. For instance, during the meetings the patients' images may be placed in a 'stack' of perhaps 120 images; these can be displayed as a video in which images may be 'clicked' forward. It is possible to 'tag' images in the stack in advance in order to stop the display at these images. As the senior radiologist put it, 'it is possible to make most flashy presentations during meetings, if you want to and have the time'.

In a cooperative project, an electronic network was set up between the respective radiology departments of the Sahlgrenska University Hospital and Skövde Hospital in Sweden. The aim of the project was to send CT (computer tomography) images of the skull from Skövde to Sahlgrenska for specialty consultation and in complex emergency situations. The idea behind the emergency procedures was that radiologists at Sahlgrenska would be able to evaluate, from a distance, whether the patient should be sent to Sahlgrenska for specialized treatment. The communication was based on a technical link between two different computer tomography workstations at the respective departments. Both these workstations converted data from the image acquisition system into data conformant with the DICOM standard. However, since all the data elements of the pixel module are machine-related and constant for a particular CT system, and CT images in visual non-binary coding are also fixed and unique to a particular CT display system, incompatibilities between these systems occurred, creating many technical problems. It was possible to send images, but there was too much information loss in the image received at Sahlgrenska. This project became very expensive. In all, it cost about SKr 1 million. It was used for half a year, and 10 patients were diagnosed during this period. As the radiologist in charge put it, 'There was too much technical trouble, and it cost too much. We ran out of motivation to continue the project'.

The intranet one and two are essential during the ad hoc discussions between radiologists and clinicians. To access patient reports and images the radiologist enters the patient ID numbers into the intranet one and two. The system responds by displaying a list of patient examination. The clinician clicks on an examination in the examination list. The clinician zooms and retrieves further images. Images are compared by switching between images showing different views of the patient. During clinical work, images are retrieved in the same manner.

Each radiological report is distributed to each requesting clinic by ’transporters’. The clinician reads it and writes a summary of the radiological report into the HIS. All clinicians that have requested and obtained a pass to an intranet application have full access to all images, even before the radiologist has diagnosed them. According to the clinicians, these images are frequently used. They support the clinical work and research work as well as the discussions with the radiologists over the phone, in which both parties of medical staff can view the images simultaneously.

Medical staff at ALB said that the clinical PACS-based systems cost around SKr 150,000 for every PC installation. Simultaneously, ALB has paid a license for SKr 150,000 that covers an unlimited number of Wiseweb licenses at the hospital. As the clinical PACS are quite complex in functionality and use, while the Wiseweb is considered to be quite transparent, it has been more convenient to implement and use the Wiseweb for the medical staff. In addition, a project is to be started between central radiology department, Karolinska Hospital and the Radiology Department, Haukelands Hospital, Bergen Hospital. This project will evaluate the extent to which the Wiseweb fulfills radiologists’ requirements for image quality during remote consultation.

The intranet application will be implemented in the entire Örebro region in Sweden, in the second half of 2000, to support the communication of radiological text and images between all the medical units in this area. Radiologists expect this application to strengthen the relationship between the medical units at a modest cost.

5. How do standardization strategies Intervene in work practice?

This section explores the consequences of different strategies used in the development of electronic standards in Healthcare. This has been done by analyzing how different electronic standards, based on various standardization strategies, are designed and applied in work.

5.1. The specification strategy

It is important to emphasize that when the PACS were developed in the early 90s there was no well-established and well-tested Internet technology. Designers of digital documents and images within Healthcare were more or less forced to build large and complex standard solutions, as these were based on complex electronic medical standards. The development and application of PACS has been an important step for the use of technology within Healthcare. The PACS and RIS provide a starting point - there are image and text databases that can be opened up for a larger number of people in various contexts when linked to the Internet technology.

Electronic standards based on different standardization strategies intervene in work in different ways, as we have illustrated in this study. They do not always intervene in the ways in which they were intended. For instance, the aim of the DICOM standard was to support universal image communication in Healthcare. To do this, the specification-driven approach presupposed a common design, where one single universal standard was to be implemented in all medical units. However, this study illustrated that DICOM-compliant computer systems were not entirely identical (see section 3). This made data exchange between computer systems difficult, because it is a prerequisite that all technical nodes in large and complex networks are compatible. Thus, checking the DICOM conformance statements of two computer systems may not be sufficient to establish communication that functions well between different socio-technical networks. This means that the initial objective of PACS - to support interdisciplinary communication between various medical units - has not been realized. Instead, PACS have enhanced a more local role. They have become most important tools in the local radiological context.

A problem with the specification-driven approach is that, since it is so formal, it results in slow and complex design processes and systems (see Section 2.1). The system complexity resulted in slow adaptation to the technology. Users need extensive training to be able to retrieve and manipulate the images appropriately and accurately in a PACS. As the system is complex, they usually require an advanced technical platform, for example workstations connected by fiber distributed data interfaces (ATM). In addition, the extensive and formal specifications have made these systems very complex and expensive to develop (see Section 2.1).

Another problem with the specification strategy is that it is based on the principles of large-scale production, in which large volumes of a single common system are considered important for cost efficiency. This is why each PACS bought from a vendor is used as one coherent common system among different users in various contexts. In practice, this means that each PACS is a compromise for all its users from a local work practice perspective. Therefore, the results of this study indicate that great emphasis is placed on the development of a common standard solution designed according to large-scale production principles. It has been hard to demonstrate cost efficiency related to large-scale production principles of computer systems supporting work practice in heterogeneous organizations such as Healthcare.

The aim of the specification strategy is to embed all components into the computer system when it is implemented the first time. This is a process in which designers try to develop a system that is as complete as possible in one step. This study supports Hanseth and Monteiro’s recent criticism (in manuscript) of the specification process as all too slow and complex. It also supports Hanseth and Monteiro’s (ibid.) suggestion that the more formal the standardization process is, the slower its adoption becomes.

5.2. The prototype strategy

Electronic standards based on the prototype strategy intervene in work in different ways, as we have seen. The intranet applications were initially designed and implemented as a step towards the ‘filmless’ hospital. The objective was to support clinicians with electronic images, if images were requested, when this was a problem for the PACS. Both of these systems started out on a small scale with functionality limited to retrieving and zooming into images. The fact that the intranet applications by their nature are quite seamless and transparent meant that no user training was needed to use the standard technology. In spite of being very small-scale applications, both of these systems quickly became embedded in medical practice.

These technologies rapidly intervened in new areas of use. For instance, they served as an important tool during telephone discussions between radiologists and clinicians, just as they served as an essential tool in surgical work, medical teaching and conferences. These electronic standards quickly enrolled different meaning and roles in different social worlds, but their structure was common enough to make them universally recognizable. They supported communication of images and reports within the heterogeneous hospital network and therefore became most important in this network. The ease with which images could be distributed via intranet applications was very important, because it affected the users’ acceptance of these applications. As new features are planned to be implemented in the system, the communicative role of the intranet application may be strengthened. For example, in September an intranet application will be introduced to support sharing of all radiological image and information within the entire Örebro Healthcare region in Sweden, including five hospitals, all the primary-care units, and private practitioners.

Introducing flexible and inexpensive Internet standards has changed the prerequisites for developing and using computer systems. It opens the way for new design strategies such as the prototype strategy, with the emphasis on the development of tailored solutions based on local knowledge.

The prototype strategy is based on an evolutionary process where the application is developed through a series of versions. Each version is in use for a period, and experience with it is used as the basis for developing the next version. It simultaneously evokes a de facto process where there are fewer regulating, institutional arrangements influencing the process (Schmidt and Werle 1998). This opens up many possibilities, such as developing systems well adapted to users’ needs, starting with simple and clear functionalities. Another advantage is that the Internet technology is fairly cheap. It is a flexible system that has the potential to grow according to the organization's needs.

6. Conclusion

The study suggests that striving for communication solutions with maximal potential for application in a heterogeneous world has implications for the standard strategies applied. In this paper, we have illustrated the advantages of the prototype strategy in the development of communication technologies in large and heterogeneous organizations, such as Healthcare. It is important to stress that we are not choosing between two strategies and technologies. It is a great advantage and almost a prerequisite to have the PACS and RIS databases from which integrated sections of information can be retrieved and presented in a browser interface. What we suggest is that the PACS and Internet technologies complement each other. The time has come to apply Internet technology much more extensively in Healthcare: among other things it has the potential to open up PACS and make it more available for more users in different contexts. The Internet technology has clear functionalities and is less expensive than other electronic standards. It has the potential to grow and meet the challenges of interoperability and collaboration between heterogeneous networks of people and things. This standardization strategy has the potential to facilitate an evolutionary process where the application is developed through a series of versions with each version in use for a period; experience with the version is used as the basis for developing the next version. There are no regulating, institutional arrangements influencing the process. This opens up many possibilities in which bits and pieces of technical components are linked to the technology over time. This is contrary to the specification-driven standardization strategy that results in a formal, long and complex design process. As a result these systems are rather expensive, and need a more complex technical platform. Users have to learn the programs, and take much longer than Internet applications to become embedded in work.

This study has also illustrated that the intranet applications have quickly developed into an essential part of medical work practice. The ease with which images could be distributed via intranet applications was very important, because it affected the users' acceptance of these applications. The planned deployment of these technologies between entire Healthcare regions in Sweden is an example of this.

In sum, it was found that computer systems based on different electronic standards intervene in work in different ways, and that they do not always intervene in the ways in they were initially intended. For example, the PACS based on the DICOM standard have primarily attained a local role, although its initial aim was to support universal image communication within Healthcare. It has developed into an important tool supporting the production, retrieval, processing and archiving of radiological image data. On the other hand the intranet application based on the Internet standards primarily not designed for this particular purpose has come to support communication of images and reports within the heterogeneous hospital network.

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