The teleradiology system and changes in work practices

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Abstract

After the design and development of the teleradiology system, a work practice oriented approach was used to gain a more holistic understanding of the relationship between the emerging work practice and the newly implemented technology, and to provide information for redesigning the system. The approach which utilized ethnographically informed fieldwork and cooperative workshops was introduced. Cooperation, the chain of tasks, and articulation work of teleradiology work practice were described, with the focus on image interpretation in particular. From the point of view of radiologists' image interpretation work, a report was made on how these findings influenced the evaluation and redesign of the system. Furthermore, the problematics of distributed collaboration, reorganization of work, and education are emphasized. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

Telemedicine is a new discipline, which greatly influences the work conducted in the health care sector. New tools in telecommunication and data processing have made it possible to link remote sites with each other. One of the most important tasks is teleradiology, transmission of digital X-ray images for remote consultation. Much of the research in teleradiology has been focused on image quality in digital images [1–3] or on diagnostic accuracy [4–7]. The technological infrastructure of image transfer [8–10] and functionality of application programs have also been popular topics [11]. More recently, economics and efficiency have become important also [12,13]. Studies carried out in connection with clinical settings have been focused on clinical patient outcome [14], or time concerns and usability aspects [15,16]. Less emphasis has been put on new challenges emerging in the actual work practice after the technical aspect has been solved.
In terms of systems design, teleradiology can be seen as one application area of interactive or computer assisted cooperative work (CSCW) systems. Within systems design it is quite common to view such systems in terms of workflow, often accompanied by a chain of tasks view of work [17]. These identifiable, usually system use related tasks, however, make up only part of the teleradiology service and time spent in making it work. It is not sufficient to study only these isolated tasks, however, an investigation of actual, everyday routine activities is needed to understand the contextual details of work and interaction in ways which support the usability of the system. We know of no studies with a work practice oriented interest describing real-life teleradiology work between primary and secondary care.

The purpose of this study was to evaluate teleradiology work in a PC-based teleradiology service and to investigate how a work practice oriented approach could be used to gain a more holistic understanding of the relationship between the emerging work practice and the newly introduced CSCW technology. Furthermore, the aim was to see how this understanding could be used to provide information for cooperatively evaluating and redesigning the system.

2. Background for the study—the experimental teleradiology project

2.1. The participating radiology work communities

A teleradiology connection was built between Kuusamo Primary Health Care Centre and Oulu University Hospital in Northern Finland. Kuusamo Primary Health Care Centre is situated 230 km from the University Hospital and its medical staff includes general practitioners as well as specialists in surgery, pediatrics, gynegology and internal medicine. It is equipped with modern X-ray equipment. They perform over 14000 X-ray or ultrasound examinations annually. A radiologist visits the premises every 2 weeks to perform special examinations and report cases needing an expert opinion. In more urgent cases, the general practitioner reads the X-ray images himself and decides the correct diagnosis or sends the patient with the images to the University Hospital. Teleradiology was introduced to offer a new service in these situations, where local expertise was not available. Oulu University Hospital is the northernmost of the five university hospitals in Finland. The hospital, with a staff of 3000 and all medical specialities, is the consultancy center for an area covering half of Finland. The present teleradiology research and development program started in the Department of Diagnostic Radiology in 1991. In the beginning, most of the emphasis was put on the technical aspects of teleradiology. During the teleradiology study, the radiologists carried out everyday clinical image interpretation on computer screens for the first time. In current practice inside the department, all images are printed on films, even though MRI and CT scans are preliminarily viewed on monitors.

2.2. The process of the project

In this project, a low-cost teleradiology link based on personal computers suitable for primary health care centers with X-ray services was developed first. It was designed to enable radiological consultation through asynchronous transfer of digitized images with combined electronical requests and reports. An initial set of requirements based on previous research [3] was set by a design team consisting of three radiologists and two physicists from the Oulu University Hospital and designers from the two hardware and software companies involved. Most of the emphasis was placed on the technical performance of the system itself. In the further iterative requirements elicitation process to improve the system, the chief physician and chief X-ray technician as well as a departmental assistant at the Kuusamo Primary Health Care Center participated in video conference meetings. When the training was completed, the system was taken into routine clinical use for consultations in difficult or emergency cases between the two radiology work communities in October of 1995. The experiment ran until April 1997. During this period, a total of 375 image packages consisting of several images were transferred. During this test period, a follow-up survey
of 108 consecutive cases was made of the case distribution and of the image processing tools used by the physician during image interpretation.

2.3. The technical infrastructure of the teleradiology system

The teleradiology system at the Kuusamo Primary Health Care Center consisted of a high-resolution X-ray CCD scanner (Pinja®, Finnelpro, Tampere, Finland) with 360 DPI (dot per in.) resolution and 12 bit grey scale dynamics. The scanner was connected to archiver/communication software (Medilink®, Acta Systems, Oulu, Finland) which is run in a Pentium (Intel, Santa Clara, CA) computer platform. Requests for radiology consultation were written with the same system and sent linked with the images in electronic form. The image acquisition system was connected via a 128 kb/s ISDN link to the Oulu University Hospital, where a UNIX-based image and text server software (Medilink®, Acta Systems, Oulu, Finland) took care of the archiving. Images were reviewed with a networked PC-workstation with a high-resolution 1600 × 1280 pixel screen and teleradiology review software (Pinjaview®, Finnelpro, Tampere, Finland). Text reports were written in a separate networked secretary workstation and electronically sent back to the Kuusamo Primary Health Care Center. Texts and images were linked during all of the phases. The user interfaces ran in common MS Windows (Microsoft, Seattle, WA) platform. The database combining images and text made it possible to follow the status of consultation tasks. For a system overview, see Fig. 1.

3. Work practice oriented approach

Understanding user requirements is a major challenge in systems design. One of the ways to alleviate sensitizing the design to the contextual details of work and interaction in ways which
support the usability of the system is to conduct workplace studies and integrate them into the design process.

3.1. Ethnographical workplace studies

Ethnography is committed to study of peoples’ activities in their natural settings (as opposed to laboratory settings). This derives from a belief that particular behaviours can only be understood in the everyday context in which they occur and they have to be fitted into the larger whole (holism). Ethnography involves understanding the work from the members’ point-of-view, how people organize their behaviour and make sense of the world around them. Based on fieldwork, a descriptive understanding of the work practice is developed. The interest in understanding human activity in everyday settings calls for participant observation because people often cannot readily articulate some aspects of their work that are so familiar to them as to be unremarkable. Observations are frequently coupled with contextual interviews and informal discussions. [18–20] The power of ethnographic fieldwork is substantially extended through video-based interaction analysis. Interaction analysis is the in-depth micro-analysis of how people interact with one another, their physical environment, and the documents, and technologies in that environment. Like ethnography, it looks for orderliness and patterns in people’s routine interactions, however, it operates at a finer level of detail. [21,22]

3.2. Linking ethnography and design

The difficult question of how to link ethnography and design has to do with how to acquire, represent and transfer the knowledge gained from ethnographic analysis of user work practices in the context of technology design [18–20]. This issue has been addressed in terms of participation and types of ethnography. In concurrent ethnography, design is influenced by an on-going ethnographic study taking place at the same time as systems development. Brief ethnographic studies provide a general but informed sense of the setting for designers. In evaluative ethnography, a study is undertaken to verify or validate a set of already formulated design decisions. Re-examination of previous studies can be used to inform initial design thinking. [23] A trained ethnographer studies the work practice of some group and the insights from this study are then transferred to designers through written reports and oral presentations. Ethnographic study might be undertaken by a team of investigators consisting of ethnographers and designers and the insights and understandings would then be embodied in the experiences of the designers who are firsthand participants. A project can also be undertaken by a team of ethnographers, designers and users. In this case, the understandings and insights would be reflected in a cooperative process or in a codesigned artefact [18].

4. The study

The study consisting of fieldwork (from October of 1995 to January 1996) and workshops (March and May of 1996) was carried out in connection to the implementation and clinical use of the new teleradiology system.

4.1. The fieldwork

Interviews with design team members and participants in the use of the teleradiology system were conducted during the fieldwork (total of 12 interviews). Emphasis was, however, in studying the actually occurring clinical practice of teleradiology in everyday settings in both locations (approximately 15 working days) by observation, contextual interviews and videotaping. A total of 21 system use related instances of work was recorded (11 image interpretation sessions, four instances of typing out reports and sending them, six instances of scanning and sending images). Stimulated recall interviews [24] were carried out with the radiologists whose interpretation work had been recorded (seven patient cases). The interviewees and researchers watched the tapes together, questioning and commenting on the events recorded. Analysis of work practice started already during the fieldwork as the fieldworkers’
interpretations and formulations of the phenomena were continuously challenged by new observations. The stimulated recall interviews served also as collaborative analyses. After the fieldwork more focused and detailed video analyses were conducted with special attention on the unfolding of work: interaction and use of materials, skills, and knowledge employed in work.

4.2. The workshops

Based on the fieldwork and work analyses, two workshops were organized [25]. The communities of work practice, design and research were brought together to collaboratively evaluate and redesign the system to support the situated and contingent practices through which the work is accomplished and to address issues relevant to developing the teleradiology work practice. Participation of all occupational groups involved in the teleradiology practice was required. A video collage of actual work situations was edited to present the entire teleradiology work practice parallel to the corresponding traditional ways of working. The video collage served as a shared object of interest and helped provide a basis for the cooperative analysis of actual work practice. The participants were able to compare practices and share their experiences. They built a common understanding of the teleradiology work practice. The system usability was evaluated based on cooperatively produced emergent practical criteria. Moving on from evaluation to envisioning future use situations they started to raise informed issues relevant to both system redesign and development of work procedures.

5. The teleradiology work practice

5.1. Moulding two previously separate communities to work together

From the point of view of the Kuusamo Primary Health Care Center, teleradiology became a question of integrating and scheduling expert consultation into the other constituents of patient’s care trajectory [26]. The two previously separate communities of radiological work practice began to cooperate in a distributed fashion. They had to revise their local ways of working and establish new commonly agreed upon work procedures. The teleradiology system replaced the peripheral awareness and face-to-face communication of local work communities by asynchronous computer-mediated image transfer, request–report exchange, and occasional phone calls on critical cases. Interactive cooperation was replaced by distribution of tasks performed in geographically separate locations at sequentially ordered times. The new teleradiology work practice is depicted in Fig. 2.

5.2. The chain of tasks

After a patient’s radiological examination and initial interpretation of images, the attending physician in Kuusamo decides whether an expert consultation is necessary, in which case he or she dictates a request for a consult. An X-ray technician or a secretary scans the films, enters the patient information, types the request into the system and then sends them to the University Hospital. The teleradiologist on duty at Oulu University Hospital checks once a day whether images to be interpreted have been received. The radiologist then interprets the images of each patient case on a computer screen and dictates reports. She or he hands over the tape to the departmental secretary who types the report into the system and sends the file back to Kuusamo Primary Health Care Center. The reports are received by an X-ray technician who prints them out to be delivered to the attending physicians.

5.3. Activities aimed at ensuring a smooth flow of work

A great deal of work was carried out by the personnel in addition to the chain of tasks directly related to using the teleradiology system. A continuous stream of contingent support work was needed in “making the system work” [27] as the patient case was taken through the consultation service. This articulation work [26] was carried out both in individual tasks and on the level of
cooperating the entire process. For example, prior to the image transfer, the X-ray technician on duty prepares the patient folder. Films of the patient’s previous radiology examinations are acquired, relevant films are selected, any missing information is checked and the patient material is organized. The technician carries out all these measures to ensure a smooth flow of work in the system while scanning, entering information and sending it. Another set of examples is of activities carried out to sustain an account of the service as a formal sequential operation. The participants routinely checked whether they had a task to carry out and after “completing their bit” made sure of the next step, i.e. a sender in Kuusamo called by phone to Oulu to inform about a critical case, a radiologist handed over the dictation tape to the secretary, who in turn after typing out and sending the report wanted to check whether Kuusamo got it.

6. Image interpretation

In the current practice, smooth flow of work for image interpretation is ensured by a great deal of support work by other occupations and easy-to-use technology in the form of films on autoalternator light screens.

6.1. The changed script of image interpretation work

Radiologists are accustomed to interpreting images as sequentially ordered processes of cases in series. The alternator supports this with its magazine for light screens that are used for the temporary storage of organized films. In traditional image interpretation sessions, the radiologists are accustomed to reading the request of the following patient to determine the problem formulation while the light screens are swiftly changed between the cases. As the next patient’s pair of light screens appears, they take a quick overall glance at the films and then proceed to a more detailed interpretation process and dictation of a report. In a similar fashion, in a typical teleradiology image interpretation session, first a report was displayed on the screen followed by images. The radiologist would, however, have to wait idly while the images slowly appeared on the
screen one by one in a blown-out-size and were then reduced to fit the pre-set frame for each image. Then the radiologist would have to reorganize and resize the images to suit the more detailed interpretation process. The system caused disruptions and breakdowns in the smooth organisation by imposing a new script for image interpretation.

6.2. Dispersion of the patient’s records and the examination process

The radiologists are used to having a patient folder easily accessible on the alternator’s desk during image interpretation. Should a need for more information arise it can be referred to at least for images of previous examinations with accompanying reports and on occasion also for patient’s medical record. Material transferred via teleradiology from the primary health care center is less than what radiologists are accustomed to, being minimal (“it’s like the patient was to a radiological examination for the first time”, “there is no history”) or not sufficient (on occasion more images had to be requested to enable comparison).

Dispersion of the examination process lead to situations where the teleradiologists did not have access to knowledge that is self-evident when the examination is performed within the close proximity of one department. They may miss the locally produced knowledge related to the patient’s examination, patient related information (patient’s physical appearance, conduct and behaviour, and answers to the questions posed during examinations), and even recollections of patient’s previous examinations.

6.3. Dispersion of image articulation work

The radiologists need to be able to concentrate on the image interpretation work during the sessions. To ensure an efficient flow of image interpretation, all image-related articulation work is carried out prior to the session. The retrieval, checking, organization, arrangement and layout of films on the alternator’s light screens is done by a special assistant in the current work practice in the Oulu University Hospital. With the new teleradiology system, the tasks corresponding to the assistants’ work were dispersed into four aspects of the teleradiology system related work practice: (1) the scanning of films and transmission of images in Kuusamo—which affects the final display order and orientation; (2) the image display system—how it displays a series of images on the computer screen; (3) how the radiologist arranges the images on the computer screen at the beginning of a session; and (4) the continuous image organization and processing by the radiologist during the interpretation process. In the teleradiology experiment, the radiologists ended up doing a great deal of image related articulation work both at the beginning of each case (Section 6.1.) and also during the interpretation process itself. One factor contributing to the latter are the enhanced image processing functions. During the study they were used as follows: zoom function (enlargement) in 71% of the cases, image windowing and levelling (brightness and contrast adjustment) in 70% of the cases, image rotation (correct side up) in 25% of the cases and image enhancement (unsharp mask function) in 3% of the cases. Another contributing factor is the lack of system support for an easy way of laying out images for juxtaposition on the screen. The radiologists’ part of the system was designed based on an assumption that the transferred cases would mostly be acute ones with few images. It turned out that 25% of the cases were acute ones (report needed in less than an hour) and the rest urgent ones (75%, report needed in less than 24 h). However, many of these were control cases with numerous images (19% of the total number of cases) and even in the acute cases comparison of images side-by-side was central to image interpretation. To a great extent, the professional expertise of radiologists lies in being able to follow a change through a series of images. This is traditionally done by comparing films side-by-side on the large light screens.

7. Discussion and perspectives

New technologies necessarily provoke changes that go beyond the technical system itself. The
work practice oriented study of everyday clinical teleradiology work practice clearly illustrates that this is the case also with teleradiological systems, and it should be taken into account in designing and implementing them in practice. The study reveals important aspects that have previously been unnoticed or invisible [28]. For example, the articulation work done to ensure the smooth flow of the teleradiology service consisted of a major part of the work process both in terms of amount of activities and importance for the whole process. Several aspects of cooperative work between the two geographically separate radiology communities were also identified. Moreover, articulation work and issues dealing with cooperation were neglected or underestimated in the system design and organization of teleradiology work practice.

7.1. Evaluating the system in actual image interpretation practice as a basis for redesign

From a radiologists’ point of view, it is important that the system does not interfere with the accustomed script of interpretation and reporting by causing disruptions and breakdowns. On the other hand, it has to be kept in mind that established work practices have been formed historically, in close relation with associated technologies. Therefore, former working habits cannot always be kept as a standard way of working but should be critically evaluated. The work practice oriented approach also proved to be useful in detecting those areas of work which are essential to the primary goal, accurate interpretation of the images. The system should support the essential parts and typical tasks of work. Image comparison is an elementary component in radiologists work. Computer screen based image interpretation technologies cannot supply as much display space as the radiologists are used to with the traditional light screens. However, the need for the system to allow for easy juxtaposition of images remains. The lack of display space has to be compensated in another ways by the digitized images and computing power. Comparison could be made easier, e.g. by always displaying chest studies on the screen in the same order. Maybe new display techniques like stack or cine mode could be used more often while reading a series of computerized tomography (CT)-images. Another aspect contributing to the ease of comparison of images is the image articulation work that is done as much as possible prior to the actual sessions. It remains to be seen to what extent this can be supported by the system automatically as there seems to be a great deal of tacit knowledge involved in the articulation work carried out by the assistants. Unnecessary image arrangement tasks during the interpretation session should be avoided because they are time consuming and can weaken the radiologist’s concentration in the image reading process itself. The initial image display should give an overview of what kind of images there are to be interpreted. Also a structured way to show time order of images is useful. The interface should be simple with only relevant buttons and menus not to hinder the interpretation process.

In our system, the most often used image processing tools were adjustment of brightness and contrast as well as image zooming. Even though these features need special training and take some time, they offer advantages by revealing diagnostic information not as easily noticeable otherwise. Our system had brightness/contrast control in the mouse, and some radiologists used it in an interactive way even while examining various parts within one image. More complicated image processing features seem not be needed in the busy routine praxis.

Improvements to system usability were identified during the study. Some specific design guidelines for the development of the system’s commercial version released in the Spring of 1997 were provided. However, this remains an area where more empirical work is needed, as the introduction of new technologies is always a learning and adaption process as well as innovation.

7.2. Developing teleradiology work procedures and service

The workshops helped a new work community emerge around the new system, as the simplest
method is to let people from both ends meet each other in person! The personnel were able to discuss, compare their local procedures, and see for themselves how the work was carried out on the other end. This helped in building a shared understanding of the cooperative work process and in agreeing on common procedures, which is often a complicated issue with distributed systems. It is important to involve not only final end-users of the system but also representatives of all of the tasks that will be changed by the system in the design process. We recommend this kind of approach while implementing new telemedical services.

New technologies may introduce totally new tasks, in this case such were the scanning and sending of images in Kuusamo Primary Health Care Center. It becomes important to fit the new or modified tasks to local conditions and other practices that will exist parallel when the system is used. Furthermore, it is important to identify what kinds of skills and knowledge are needed in the new tasks: not only training in skills for the new application programs or one’s own tasks is needed, but also knowledge of other’s tasks and one’s own role in the system as a whole to help in adjusting to cooperative work.

In our system, texts (requests and reports) and images were linked together. This approach is different from many teleradiology systems, where only images are transferred electronically while texts are sent via telefax. Our system makes it easier to combine patient information and to refer back to earlier cases. However, from the point of clinical praxis, an even more extended connection to patient records is preferred. Image comparison would be easier, if earlier images could be acquired from a digital archive whenever needed. A hospital with connected primary health care centres could keep one common regional archive. This would increase the quality of care and also decrease unnecessary retakes while the patient moves from one institute to another. Also the texts need to be integrated to the electronic patient record. Today, the primary health care centre prints the reports out in paper form. In the future, the physicians can automatically receive reports directly into their terminals. Then teleradiology would finally support medical work flow as a part of vital patient information.

8. Conclusions

A technological system alone does not ensure the efficient and smooth operation of teleradiology service. The hidden aspects of work have to be detected and made visible by a work practice oriented study. They are valuable to the success of the entire teleradiology process and may determine whether the system is accepted. The technological system has to be fitted into work practices, organization and work procedures have to be readjusted, and there is a need for additional education and training. In order to develop a good teleradiology service, the above issues have to be taken into account.

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References


