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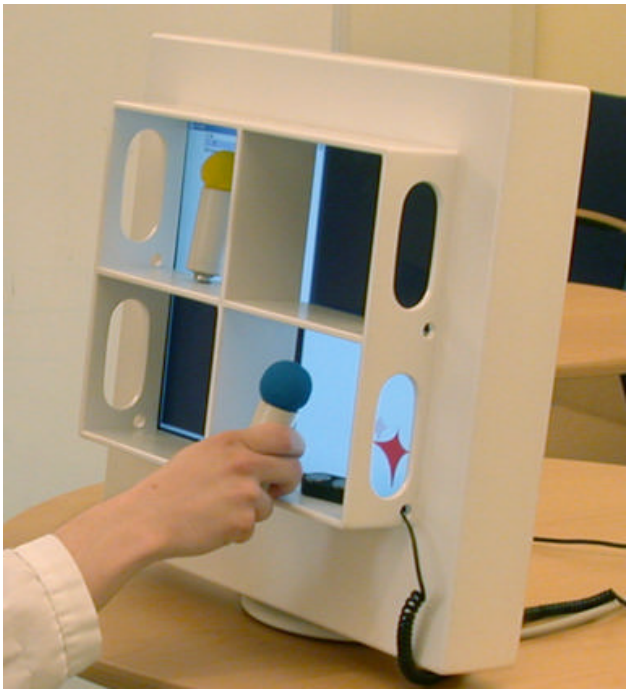
Designing for Awareness and Accountability with Tangible Computing



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Abstract

This project has been devoted to design a computer system with a tangible user interface, in the context of future supervision of remote drop-in dialysis patients. The tangible computer system was developed as an example of how two concepts in human work, accountability and awareness, can be supported through tangible user interfaces. A current trend within CSCW discusses accountability in design in terms of how software should make its own actions accountable. We choose to use an alternative route, namely to use the tangible interface for explicating nurses and patients actions for each other. Explicating actions is key benefit with a tangible interface in work environments that is physical co-located. We conclude that our strategy can be investigated further in settings where the work is carried out in a physical co-located space.

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Future Scenario of the Dialysishouse

The scenario describes our vision of how our design solution, *the Dialysishouse*, would be used. It is a vision of the future describing how Martin, a dialysis patient, conducts dialysis within the Drop-In system. Nurses at the department several miles away supervise him remotely, with the help of the Dialysishouse solution.

Martin Conducts Remote Haemodialysis

Martin opens the door to the dialysis pavilion. In the room stands a chair with a dialysis machine beside it. It is Monday afternoon at 4 pm. The sun was shining today, one of the first warm summer days, so Martin rescheduled his dialysis treatment from the morning to the afternoon.

Martin starts to dress the machine with tubes and a dialysis filter. When all the tubes are connected to the machine, he starts the machine self test. While the machine tests its different parts, Martin writes down the production numbers of the tubes, needles and filter that he uses for today's treatment, in his medical record. He also weighs himself in order to estimate how much body fluid to remove during the treatment. Today he weighs 68,5 kilos and his dry weight should be 67. He writes down the numbers in his medical record.

Meanwhile, nurse Betty at the hospital's dialysis department 20 miles away, has finished starting up two dialysis patients in the department. She looks at her watch and notices that the time is 4 pm. She looks at the whiteboard hanging on the wall in the corridor and sees that today Martin, Elsa and Bertil have booked time for remote dialysis. Martin's treatment is scheduled to start 4 pm, while Elsa and Bertil started an hour earlier. Next to the whiteboard stands the Dialysishouse with four rooms. In two of the rooms there are sculptures representing Elsa and Bertil. Betty grabs a third sculpture, standing on a shelf next to the whiteboard, and places it in one of the free rooms in the Dialysishouse. The room lights up and its back wall show a progress bar without any information. Betty understands that Martin probably is a little late with the start-up of his treatment and walks away to continue to take care of her patients in the department.

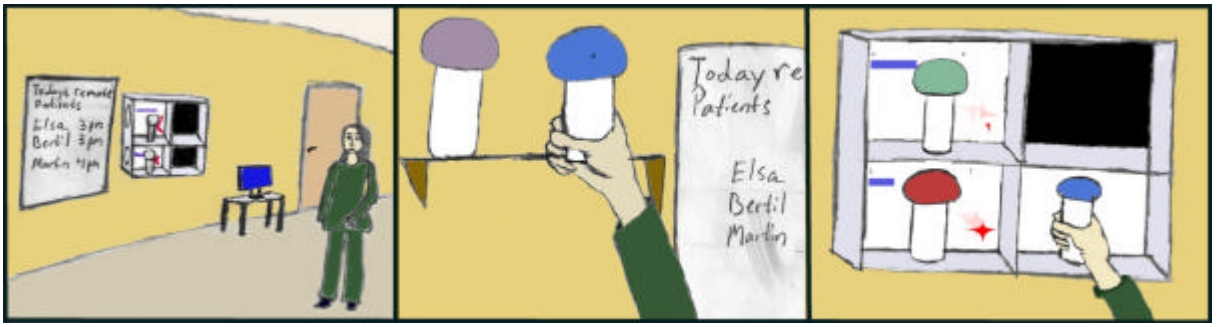

Figure 1. *Nurse Betty places a sculpture in the Dialysishouse to start the visualisation of Martin's treatment.*

The machine has now successfully finished the self-test and Martin writes down the settings in the machine record that lies on top of the machine. He sits down in the chair and cleans his arm with disinfectant. He unpacks the two fistula needles and inserts them one at the time into the fistula in his right arm. In order to prevent the blood from coagulating, he takes a dosage of heparin with the venous needle. Then he attaches the artery tube from the machine to the artery needle in his arm and starts the machine. While the blood is filling the artery tube, he sets some parameters on the machine. Today he sets the duration of the treatment to three hours. He sets the machine to remove 1,5 litres of body fluid and the blood flow rate to 300 ml/min. The artery tube is now filled with blood. Martin attaches the venous tube to the venous needle and the blood passes the dialysis filter, flowing back into his body. The treatment has now started.

At the department, the room in the Dialysishouse where Betty put Martin's sculpture starts to show information on its wall. The progress bar shows the estimated time of the treatment, and a graphical figure shows an overview of the treatment status. Nurse Ellen passes through the corridor on her way to fetch some medicine in the medical storage. She notices that a third person, Martin, now has started his remote dialysis. All the patient rooms in the Dialysishouse are neutral and Ellen passes without looking closer.

Martin now measures his blood pressure with a blood pressure gauge on his left arm. It is a bit high today, but it seems ok. He writes down the blood pressure and the values from the machine into his medical record. Then he lies back in the chair, turns on the TV and watches his favourite soap opera. He has approximately three hours until the treatment is finished. It suits him better to have three hour treatments a bit more often than the weekly three times of five-hour-treatments at the dialysis department that he had before. Now he is able to plan his treatments on shorter notice, and adjust them to TV-programs, weather and different occasions.

Betty is going to have her coffee break now, but decides to stop and look a bit closer at Martin's treatment status on her way. She moves closer to the Dialysishouse and sees that Martin has started his treatment now. The progress bar shows half-an-hour into the three-hour treatment. No alarms show on the bar, which was expected. Martin is a calm patient who doesn't have many alarms or complications during treatment. Betty knows him from before when he used to travel to the department. She used to feel a bit sorry for him, since he was very independent and managed most things without a nurse. It's good for him that he finally is able to plan his treatments so he can live the active life he wants to. She decides to look closer at the detailed information about the treatment and grabs the sculpture and places it on a shelf beneath a computer screen. The screen lights up and shows detailed information about Martin's treatment. She sees that he keeps to his usual settings with a blood flow rate of 300 ml/min, which is good, and removing 1,5 litres of body fluid.

Simultaneously, Martin notices that the sculpture standing beside his chair lightens up. He understands that a nurse is looking at his data and remembers that he wanted to ask about his high blood pressure. He presses the sculpture's head to indicate to the nurse that he would like to speak to her.

As Betty is studying Martin's data, the sculpture is illuminated. It is Martin wanting to talk about something. Betty picks up the headset hanging on the side of the dialysis house. "Hello Martin", she says, "It's Betty here, how are you doing?"

Figure 2. *When Betty picks up the sculpture, Martin requests a chat.*

Martin hears Betty's voice through the speakers in the room. "I'm doing fine Betty", he speaks towards the nurse sculpture, where a microphone is placed, "I just wanted to ask you… my blood pressure is a bit high today but there has been no problem so far. What do you think?"

Betty looks at Martin's settings on the screen. "You could try to lower the temperature to 36 instead", she answers, "That may help." "Thank you Betty", she hears Martin say. "I'll try that. Bye." The temperature setting changes on the screen and everything looks normal. Betty puts the sculpture back into the treatment room in the Dialysishouse. The information disappears from the screen and the treatment room lights up again. Betty goes to have her coffee break.

Another hour passes and there is only half-an-hour remaining of the treatment. Martin is feeling drowsy. The TV-news is not telling anything interesting today. Suddenly he hears the machine give an alarm and sits up looking at the screen. He resets the alarm by pressing a button on the machine and the alarm goes quiet.

At the department a couple of nurses are passing the corridor on their way to the office. In the Dialysishouse an alarm symbol is showing on the progress bar. The nurses don't notice it and disappear into the office.

Martin sees that the alarm was an artery pressure alarm when he looks at the screen. He checks the needle to see if maybe it has moved and affected the blood flow. The needle looks fine though, and the machine shows a stable artery pressure. Martin decides to measure his blood pressure and puts the blood pressure gauge on his left arm. A minute later he finds that the pressure is all right. Maybe he just moved a bit which caused the needle to suck to the artery wall and hinder the blood flow. He lies back in the chair again and continues to watch TV.

Nurse Betty has finished her patients at the department and is now passing the corridor to throw some garbage. She throws a glance at Martin's treatment in the Dialysishouse. The progress bar is almost filled and she sees that an alarm has happened recently. Since no sound alarm has been activated at the department she concludes that it was nothing serious. Martin has received a good treatment.

The treatment has now finished and Martin removes the needles. He throws away the tubes and needles and tidies up. The time is past 7 pm and he is going home to have dinner with his family.

Introduction

We have designed and implemented a prototype of a tangible system for supervising patients in remote dialysis. The system is designed to be used by the nurses at the dialysis department, while carrying out their main tasks, such as attending to dialysis patients at the department and administrative work. The purpose is to explore how a tangible interface can support, in the future context of supervision of remote drop-in dialysis patients, accountability and awareness by at-a-glance. The aim has not been to design the solution for supervision, but to explore how tangible computing can support these two CSCW concepts.

The project is conducted within a greater project between Blekinge Institute of Technology, Baxter AB and Karlskrona Hospital, which aims to start Drop-In dialysis in the Blekinge County. We started with the design idea *Mushroom*, which was inspired by papers and reports written by a Ph. D. student in a previous dialysis project (Tap, 2001). The Mushroom was rejected after closer study of the work place. Instead the result became a prototype called the *Dialysishouse*.

We begin the report by discussing awareness and accountability and their relation to tangible computing, arguing that tangible computing can support these CSCW concepts. Haemodialysis and the Drop-In vision are then explained followed by a description of our work process, as background information. After that we describe and analyse the work practice as it occurs today at the dialysis department of Karlskrona Hospital. Finally the design solutions are explained and discussed in relation to awareness and accountability.

Related Research Areas

We chose to focus our report around the research area Computer Supported Cooperative Work and the design approach tangible computing. Of course our work relates to other research areas. For example there are interests within HCI in alternative user interfaces like tangible computing, which we are addressing. The idea of embodied interaction, presented by Paul Dourish (Dourish, 2001), also deals with the relation between social and tangible approaches to interaction. Similarly we try to relate the nature of social action with tangible computing and design, but focus specifically on awareness and accountability.

Awareness, Accountability and Tangible Computing

The research area Computer Supported Cooperative Work (CSCW) offers valuable insights of the nature of work, which has influenced our design. We are particularly interested in how to support the concepts awareness and accountability that characterise work. In this project we have chosen to use the notion of at-a-glance to approach these two concepts. It is our argument that the physical attributes of tangible computing support these special characteristics better than applications on a desktop PC. In this section we explain the concepts and ideas worked with and how tangible computing relates to them. It will serve as a framework for evaluation and reflection in our conclusions.

CSCW concepts

Within CSCW, studies of work places have shown that how work is carried out is inseparable from the setting in which it takes place (Suchman, 1987). A key notion is that work arises in the situation rather than merely being an execution of pre-defined rules and plans. Plans are resources for work rather than strict procedures. Smooth workflow is an accomplishment by members' continuous adjustments of plans to the situation at hand.

Due to this situatedness of human work, and the complexity of context, designers cannot fully anticipate and define sequences of action. Computer applications are often, if not always, used in ways unanticipated by their designers. Dittrich considers the relation between the computer application and a specific use situation to be a creative achievement of the users (Dittrich, 1998). She comes to this conclusion based on a case study, which showed how a number of groups each used specific software functionality completely differently and none in a way intended by the designer. The unanticipated use has also been recognised by Robinson. He states that work is best supported by the provision of resources, rather than something that tries to define a strict procedure (Robinson, 1993). Moreover, he argues that well designed artefacts should provide for different dimensions of work such as peripheral awareness, predictability etc. These comments have inspired us to design for some of the characteristics of work.

In order to design a flexible tool that supports the nature of human work we have chosen accountability and awareness to base our work on. To accomplish this, we intend to use the notion of at-a-glance.

Awareness

Awareness is a concept that describes how members[1] in a setting accomplish coordination of work through knowledge about each other's actions. In a work setting different signals and cues are constantly emitted and interpreted by members during the course of work. As explained by Schmidt and Simone:

[1] By "member", we intend the ethnomethodological definition: someone who shares the common sense understandings of a practice, i.e. knows how to act appropriately to a setting (Dourish and Button, 1998).

The acquisition pertaining to mutual awareness is non-intrusive in the sense that it does not intervene in the flow of work by enforcing a response: it merely enables the actor to adjust his or her activities to the perceived or projected state of affairs so as make his or her activities mesh seamlessly into the collective effort. (Schmidt, Simone, 2000, p 6.)

Awareness is not automatically produced. It evolves from delicate practices. Actors make their work visible in a way that is relevant to their colleagues' situation. The signals and cues emitted tell for example that activities are being done, if they will affect the work of colleagues and whether or not the work will meet time constraints. There are attempts to define different types of awareness, such as peripheral and mutual. However, we choose not to make the distinction, because they are closely entwined. Instead we refer to the overall phenomena as "awareness".

We have chosen to focus on awareness since it is essential in coordination of work. When members are aware of each other's actions, they have the possibility to adjust their work accordingly, which is necessary for coordination of work. To achieve awareness the signals and cues emitted must make sense to the members. This phenomenon is called accountability by ethnomethodologists.

Accountability

Accountability is another interesting term we have decided to work with, since it is important for members not to simply know the result of action but also to recognise the course to achieve it in order to coordinate work.

We use the ethnomethodological definition of accountability, which means that members make sense of action in the context in which it arises. Accountability is the property of action being organised so as to be "observable and reportable" (Dourish, 2001). It is both being recognizably rational as it emerges in context and organized to allow this. A member does not simply perform an action, but perform it in such a way that it can be recognised by other members. Action is organised to demonstrate what it is so that other members may interpret it and coordinate their work. Since members share a common sense understanding of the setting, and thus know how to engage in an action, they also have the competence to understand it. As we interpret accountability it is not a static feature, but a dynamic production of the members in situ.

It may be debated where accountability is found: in the eyes of the beholder or in the action. In our opinion it is a mixture. What is important to keep in mind is that accountability arises in the use situation, and is not under control by designers. However, what designers may control is making action observable. By designing artefacts for making actions visible, we design for accountability. The artefacts' impact on visibility of actions and contribution to accountability has previously been noticed in work place studies. A feature of artefacts supporting accountability has been named at-a-glance.

At-a-glance

Awareness and accountability of action can be supported through artefacts. Robinson exemplifies how old-fashioned dials in a French nuclear power station played an important role in the operators' awareness of each other's work (Robinson, 1993). They could easily see which part of the system was of concern when someone went over to some dial and stared at, or tapped it. Thus it was easy to read the context of any action that might subsequently be taken. The design of the artefact allowed for members to see what others were doing at-a-glance.

Robinson also exemplifies how a hotel keyrack allows for experienced personal to interpret what is going on in the hotel by seeing which keys are in and messages placed in the pigeonholes. The keyrack conveys current overview information to both staff and guests. The staff has an opportunity to glance at the rack to see the hotel occupancy. The guest in turn can see if other guests are in or out.

These are two quite different settings and artefacts but they show from different view points how useful at-a-glance can be. Worth noticing is also that this visibility of action and overview is tightly coupled to the physical design of the artefacts. This is why we have chosen to design a tangible interface for at-a-glance.

Accountability and Awareness in Design

We consider accountability and awareness useful to describe the nature of human work. As it is our interest to design with them in mind, we have examined how they have been used in design so far.

There are projects that have designed for awareness, but we have not found any design approach explicitly dealing with the concept. An example of how awareness has been used in design is the Tukan project (Schümmer and Haake, 2001). It is an integrated environment for software development that supports awareness of co-workers through indicating changes in source code with icons on the display. Also awareness of colleagues' availability for communication is supported through signs representing the ongoing activities. The Tukan environment is intended to be used by developers working in the office or remotely. It is suitable for work conducted by a computer, where the attention is on the screen. The dialysis department is a completely different setting with different requirements than an office environment where work is sedentary and conducted in a shared information space like the Tukan project.

Figure 3. *Visibility of interaction with a conventional desktop PC.*

Unlike awareness, accountability has been treated explicitly in a design approach. Technomethodology is an attempt to bring accountability into software system design (Dourish and Button, 1998). The idea that

systems are to be designed to account for themselves through opening up the abstractions that the system offers so that they can convey aspects of the mechanisms which lie behind them. The system should make its actions "observable and reportable", for example by visualising the different stages of file copying within a LAN.

We find that accountability in design so far has been more discussed in terms of how a system should account for itself. This is of course important for making a system understandable to people so that they know how to use it. However, it is our interest to investigate another aspect of accountability in design, namely the design's possibility to facilitate accountability of action within a setting. Instead of focusing on how the system should explain itself to the users, we want to explore how the system can help making people's actions visible, and thus observable and reportable.

The usage of awareness and accountability in design described does not cover our focus. Instead we turn to another design area for inspiration. The nuclear power station and keyrack examples, hints how to support the aspects of awareness and accountability that are our interest, through physical design. This leads us to the area of tangible computing.

Tangible Computing's Relation to Awareness and Accountability

As a reaction to the conventional PC interaction model, alternative design approaches have arisen, focusing on bringing computation into physical entities, aiming on an interaction model more integrated in the world in which we operate. Examples of some approaches are Tangible Bits, Ubiquitous Computing and Wearable Computing. Like Dourish (Dourish, 2001), we refer to this alternative model of interaction as *tangible computing*. A diversity of different tangible applications has been developed through the passed decade. There are several possible advantages with tangible computing compared to the traditional desktop PC. When looking closer at the applications we find valuable ideas about how to design for awareness and accountability.

The Tangible Media Group, led by Hiroshi Ishii, at MIT Media Lab is one of the important research groups exploring tangible computing. Their specific approach is Tangible Bits, focusing on bridging the gap between the physical and virtual world. They have developed several research prototypes. One of them is Tangible Geospace, a specific application of the MetaDesk (Ishii and Ullmer, 1997). It is a two-dimensional geographical map that is projected onto a surface (MetaDesk). When physical objects, representing a specific building, are placed on the surface, the map is aligned with the objects. The user may adjust the maps scale and focus by moving the objects. As the example Geospace shows, physical devices allow for multiple points of interaction. An action can be achieved through the coordinated use of several artefacts instead of one mouse or keyboard. There is not one centre of control; instead there are several points of interaction. The Geospace buildings are all points of interaction. By moving a pair of buildings on the Geospace map, the display of the map will change according to the objects' relation. This also shows the possibility of non-sequential interaction, which supports collaborative use. The movement of several objects are allowed to

happen at the same time, instead of the common sequentiality in the desktop PC interaction, due to its limited points of interaction (mouse, keyboard).

When reflecting on the design of Geospace we found attributes that inspired us how to design for accountability. When a user moves a building on the map, it is observable to other people that a building is moved and which building is moved. The physical interaction model combined with the identifiable buildings conveys what the action is. Because of it's physical constitution it is observable on the distance within a room. This is an interesting idea for design that we have explored further in the Mushroom and the Dialysishouse.

Dangling string or, "Live Wire", was developed by Natalie Jeremijenko at Xerox PARC in 1994 (Weiser and Brown, 1996). It was an eight feet long plastic string, hanging from the ceiling in a corridor. The string was connected to a stepper motor, placed in the ceiling, which in turn was connected to a device on the local Ethernet. Every time a data packet passed by on the Ethernet, the stepper motor would move, and its movements would be passed on to the string. That way, the string showed how busy the network was. The Live Wire shows how information about the status of an Ethernet network can be provided at-a-glance. It exists in the periphery of the user attention, available in all their different work tasks in the area. Users thus achieve an awareness of the network traffic, information that can be useful for example troubleshooting problems when printing or saving electronic documents within the network. The physical features of the string, taking up space in the room and movements, support at-a-glance and awareness.

In tangible design the physical properties of the interface suggest its use. Everyday things like coffee pots are designed to tell how to pour the coffee, where to fill it up and how to carry it safely. In the same way, tangible computing suggests its use, but enhanced with computation. The HandSCAPE is a digital measuring system, which takes advantage of the physical form of a measure tape (Lee, et al, 2000). This is an example, where the measure tape suggests, through its physical form, that it can be pulled out to match the length of an object. It can be used in all directions in a room, recognising spatial dimensions of objects. The data of the measurement is then used to create 3D models in a computer.

As described, there are many suggested benefits of tangible computing. The projects described above, and many others, highlights these benefits in different domains through devices for delimited tasks. They are mainly mind shifters, which challenge our conception of how user interfaces should be designed. The design theory in these projects is rather limited.

One attempt to form a conceptual framework for tangible user interfaces (TUI:s) have been presented by Ishii and Ullmer (Ishii and Ullmer, 2000). They have introduced the MCRpd interaction model for identifying and discussing key characteristics of TUI:s. MCRpd leverages from the Model View Controller (MVC) archetype in software design and describes the roles of physical and digital representations, physical control and underlying digital models.

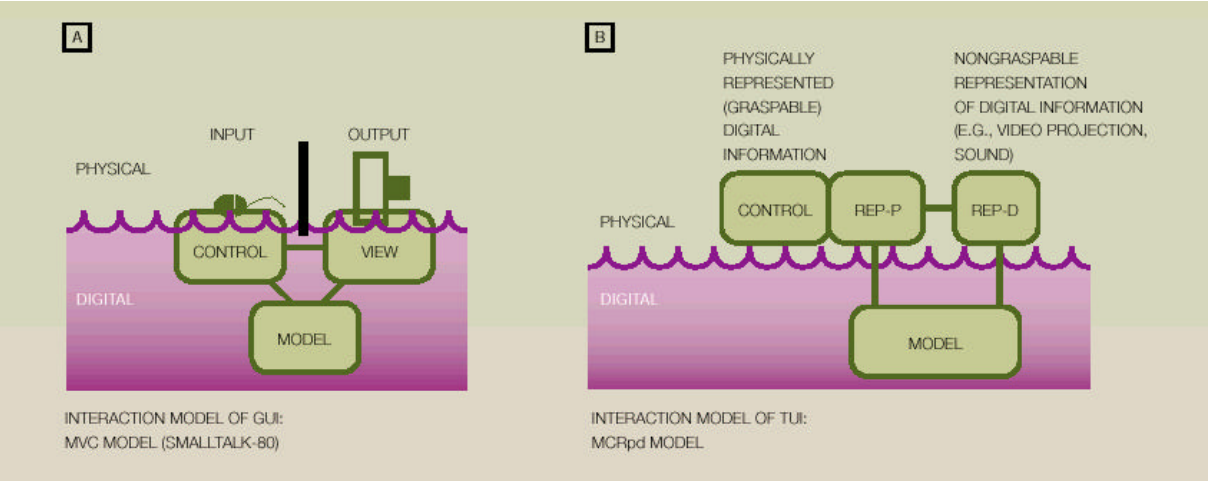

Figure 4. *GUI and TUI interaction models (Ishii and Ullmer, 2000, p 917).*

The MCRpd model shows that physical representations (rep-p) are computationally coupled to underlying digital information (model). The physical representations also embody mechanisms for interactive control (control). Physical representations actively mediate digital representations (rep-d), which means non-graspable representations such as graphics, sound or video projection. Figure 2 shows the differences between the interaction models of GUI and TUI as presented by Ishii and Ullmer. It illustrates how much of the interaction in a GUI interaction model takes place in the digital world with windows, menus etc. With the TUI interaction model on the other hand, the interaction takes place in the physical environment, making it visible to others. Therefore we consider it natural for tangible interfaces to support accountability of action.

In their TUI framework, Ishii and Ullmer suggest different application domains where they believe TUI:s can prove valuable. Amongst their categories "Collocated collaborative work" attracted our attention. Their argument is that multiple points of interaction naturally provide for collaborative work. They also argue that:

"Tangible interfaces offer the potential for supporting computationally mediated interactions in physical locales and social contexts where traditional computer use may be difficult or inappropriate." (Ishii and Ullmer, 2000, p 925)

We agree with Ishii and Ullmer in this statement. However, this is also where they fall short in our opinion. Their framework in its current state fails to explain how tangible interfaces would support these domains. We want to look further into this statement and argue that it is viable, because tangible computing can be designed to support awareness and accountability of action. We have tried to made use of the tangible computing ideas in the complex context of supervision of patients in remote haemodialysis. To make use of the tangible attributes, we have evaluated them as means to achieve awareness and accountability in the future work setting.

Haemodialysis and the Drop-In Vision

In this section the current treatment system of haemodialysis and the future vision of drop-in dialysis are described. Furthermore the need for supervision of remote dialysis patients is discussed drawing from experiences from the Canadian remote dialysis project Daily Nocturnal Haemodialysis.

Haemodialysis

The most important functions of the kidneys are to secrete slag that is formed during the metabolism, and to regularize the secretion of salt and water, so that the body fluids volume and composition keep normal. Different renal diseases may lead to reduced or failed functions. If not treated, the renal failure causes death. In 1998 there were about 2700 patients receiving dialysis treatment in Sweden. Each year the number of patients increase with approximately 1000. There were dialysis departments at 60 hospitals in Sweden in 2000. A small number of patients conduct their dialysis treatment at home. Dialysis treatment can be done in different ways, of which haemodialysis is one.

In haemodialysis, blood is taken from a blood vessel and lead through a filter, an artificial kidney, in order to remove slag. The filter consists of thin membranes. The blood circulates on one side of the membrane and dialysis fluid on the other. The concentration of salts of the

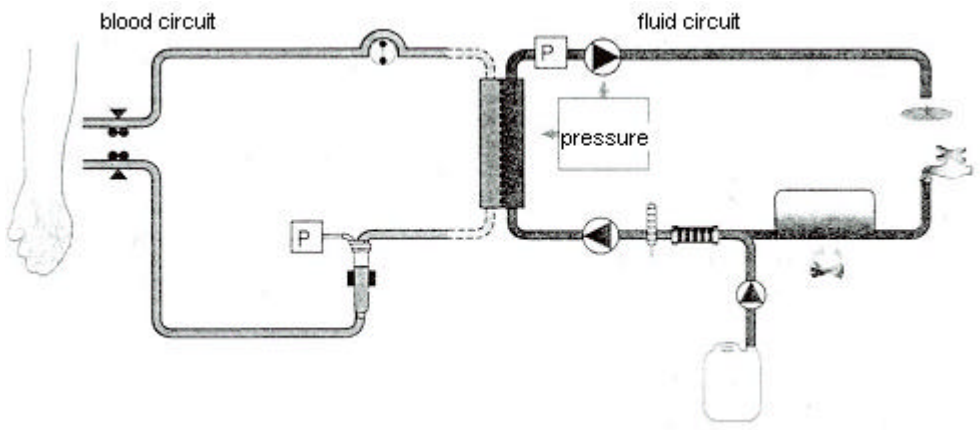

Figure 5. *The priciple of haemodialysis.*

dialysis fluid is almost the same as the one wanted in the blood after the treatment. Smaller particles, slag, pass from the blood through the membrane into the dialysis fluid. Since patients have reduced or none urine production, they also need aid to remove the surplus of fluid. This is done during the dialysis and is called ultra filtration. There is a pressure difference on the membrane, which causes fluid from the blood to transcend to the other side.

At the present, the majority of haemodialysis patients receive three treatments per week at the hospital. Each treatment takes about five hours plus preparation and closure time.

Vision: Drop-In Dialysis

Dialysis treatment is today a considerable part of a clinical department's activity. One of the visions for the future is Drop-In dialysis, which gives the patient the opportunity to receive treatment closer to the home, at a local dialysis pavilion, instead of travelling several miles to the dialysis department at the hospital. Drop-In dialysis shall give the patient more flexibility to decide the time and length of the treatment, which would lead to better quality of life. Drop-In dialysis would make it possible to receive more frequent and shorter treatments. The patient shall also be able to chose and alter where his treatment is to be done, at home, in the drop-in pavilion or at the hospital, depending on his condition.

The aim of the Drop-In dialysis project is to develop a system with which patients can carry out treatment without the physical presence of specialised dialysis-staff. This is to be done with confidence, maintained or improved quality and optimum medical safety. The prototype that we have designed treats the supervision of patients.

The Drop-in dialysis vision implies that the patient and nurse's roles in dialysis treatment change. The patient will be responsible for managing his own treatment. In turn, the nurse's role will be counselling and supporting, instead of taking care of the patient and running the treatment. She will also see to that the treatment complies with the notion of good dialysis, and that the patient manages alarms. This means that the supervision mainly will consist of keeping an eye on the treatment rather than solving problems and handling alarms.

Remote Supervision of Patients

In this project it is assumed that trained dialysis staff at the dialysis department will supervise patients conducting remote dialysis. However, the need for supervision is debated.

Daily nocturnal haemodialysis (DNHD) at home with aid of remote monitoring has been conducted in Toronto, Canada since 1994 (Pierratos, 1999), and in New York, USA since 1998 (Hoy, 2001). In these projects an observer monitors up to 30 patients for 10 hours nightly, 6 nights per week. Data from each patient's dialysis machine is downloaded in real time over the Internet. All alarms are detected and recorded. If a patient does not successfully reset an alarm within 2 minutes, the observer calls the patient and assists.

Reports show an average of 1.7 alarms per patient per night, 90% arterial (Pierratos, 1999) and 1.1 alarms per patient per night, 70% arterial (Hoy, 2001). The most common alarm are thus arterial, which means that the needle sucks to the walls of the vein and hinders the blood flow. It is managed by adjusting the needle so the blood flows well again. If there are critical situations, such as blood leak or air in the blood, the machine stops the blood flow and the treatment ends. We conclude that the worst-case scenario is thus that the patient has to end the treatment and postpone it.

Dr. Pierratos has stated that he is not sure that a definite need exists for remote monitoring. If something catastrophic happens, the remote observer can do little. Still, Hoy points out that remote monitoring allows for more rapid intervention, calling 112 for example.

The rationale for remote monitoring is to enhance safety. The experience of DNHD is still considered too limited to let go of the monitoring, according to both Pierratos and Hoy. Remote monitoring also allows more accurate data collection since data is downloaded in real time from patients' dialysis machines. It shows whether the machines run, exactly how long they run, what alarms occur, and how quickly the patients respond. Blood flow rates and dialysate flow rates are known. Each patient's data can be reviewed each month at the DNHD clinic. It is believed that accurate data collection is essential for monitoring patients individually.

Another reason for remote monitoring is to support patients who are less comfortable with technology. To make the technique viable for more people, we will need simpler technology, but the patients will still need technical support. When patients need assistance, the observers help them troubleshoot problems in real time, allowing dialysis to proceed where it otherwise might have been discontinued.

Patients from the projects has expressed that they feel better when they know they are monitored, even though the possibilities for the observer to interfere are limited. One third of Hoy's patients say they would not have opted for the modality without remote monitoring. Hoy thinks patients deserve technical and emotional support that remote monitoring provides until more experience has accumulated. Normally, every home haemodialysis patient must have a trained partner. By remote monitoring, patients are not required to have trained partners.

The DNHD project states that monitoring of patients might not be necessary even though it cannot be totally rejected. We choose not to take a stand in this matter. Instead we take for granted that there is a need for supervision of patients. What we learn from the DNHD project is that the monitoring system is used for technical support, increasing the patients' feeling of safety and when a patient for some reason does not take an alarm, there is someone who will notice it. This means that the system must monitor alarms, but that also that it will not be it's most frequent usage. It implies that a core function has to be support. In the DNHD project a PC is used for monitoring, which means that the observer sits by a computer and watches the patients. In our case, we assume that the nurses will supervise remote patients while carrying out other tasks at the dialysis department at the hospital, which means that they will not have time to constantly watch a computer screen. Therefore the system must support awareness and accountability in a different way. We argue that tangible computing is a solution.

Work Process

We intended the supervising system to be used by the nurses at the department while they were carrying out other tasks like taking care of patients at the department and administrative tasks. To understand the settings' implications for design we studied how the nurses co-ordinate their work and how they supervise their patients at the department. Existing research material from previous studies of the dialysis department in Karlskrona functioned as introduction to the field. In addition we have conducted our own quick and dirty study of the work practice. The design work has comprised workshops and designing mock-ups, resulting in a prototype implemented in Java.

Examination of Previous Material

Since the Drop-In Dialysis project started in 1997, there have been several research projects at the dialysis department in Karlskrona. One project examined the interaction between nurse and patient, and their use of artefacts, in video- and audio communication (Sanchez Svensson, 2000). Furthermore, the nurses' coordination of work at the department, focusing on managing alarms, has been investigated (Tap, 2001). Diagora is a third project, which is a compilation of design ideas for today's work at the department (Sanchez Svensson et al, 2000). These papers have given insights in how work is conducted at the department today and the problems of the Drop-In vision.

The research projects have also produced video films from the ethnographic studies, which have been valuable as introduction to the field. The video films answered many of the initial questions regarding in our ethnographic study. Above all, they informed about the procedural course of action during treatment, the dialysis machine functions and the different types of alarms. Still, the information gathered from previous material was not satisfactory. We lacked material on what actually happens during treatment and how the nurses supervise their patients. Therefore we decided to make a quick and dirty ethnographic study.

Quick & Dirty Ethnographic Studies

Quick and dirty ethnographic studies are used for obtaining specific information about a workplace in short time (Hughes et al, 1994). The fieldwork is normally used for informing design. Its duration is short relative to the size of the task. In our case, the purpose of the project has been to explore design solutions. Therefore we have chosen to apply the quick and dirty approach to get sensitised to the setting.

Focus of the Study

The work at the dialysis department is about making sure that the patients receive good quality dialysis treatment. In Drop-In dialysis the quality has to be the same or possibly better. Remote supervision is to aid the patients and nurses to maintain good quality. To be able to make design decisions we have to understand what good dialysis quality is and how quality is

maintained in the existing work practice. Information about how nurses supervise patients and what aspects they look at, is essential for deciding what information the system should convey and in what way. It is also important to recognise how Drop-In dialysis will affect the roles and division of labour in the quest for quality dialysis. This will have impact on how the system is designed, for example, regarding when and how the system should call the nurses' attention. We thus focused the quick and dirty fieldwork on finding out how nurses and patients cooperate to maintain good quality dialysis.

Fieldwork

During the quick and dirty workplace study we made two visits at the dialysis department. The first visit, we observed the treatment of the morning patients and talked to both nurses and patients about the work. We also got a guided tour around the department. Before the second visit, the nurses helped us to get in contact with a patient representative for patients that could conduct remote dialysis in the future. He was representative since he did not have many alarms during treatment. Also, he was taking active part in managing his own treatment.

The purpose of the second visit was to videotape a 5-hour treatment to be able to analyse how the nurses supervised a patient and what happened during a treatment.

Interaction Analysis of Treatment

From the five-hour videotaped case of treatment we picked out clips where any activity was going on, such as conversation, alarms or the hourly note taking. We analysed the video clips at three occasions: first ourselves, then during a workshop at the Department of Human Work Science and Media Technology and finally at a workshop at Umeå Institute of Design. The clips also served to inform participants about the setting during the workshops in order to discuss design solutions. It was valuable to analyse the clips together with different professionals, since they gave different perspectives.

Design

During the project we have constructed several mock-ups of potential design solutions. One of these mock-ups was chosen for implementation in a prototype. As part of the process we also arranged a workshop at the Umeå Institute of Design to discuss different design solutions.

Figure 6. *An early mock-up of the Dialysishouse.*

Mock-ups

We have been working with two main concepts during the project. The original idea was the Mushroom metaphor, where Mushroom sculptures visualised alarms of remote patients. This concept proved insufficient for the setting, which made us look for another solution. The final concept

was a dollhouse metaphor, called the Dialysishouse. The Dialysishouse visualised not only alarms, but also other quality aspects of treatment. We made mock-ups and sketches of both the ideas to visualise the solutions. It was an important way to explore the physical properties of each idea, since we were designing a tangible solution.

Prototyping

As mentioned, the Dialysishouse mock-up was chosen for implementation. The prototype implemented consists of two parts: software and a physical interface. The physical interface is built as a wooden house with small rooms where sculptures, representing patients, can be placed. IButtons serve as an intermediate, communicating the identification of the sculptures to the software. The software developed consists of a server environment and two clients. The server and clients were built around the Java Enterprise technologies.

Workshop with Umeå Institute of Design

This workshop with Industrial and Interaction designers was conducted in order to discuss tangible design solutions. We presented the findings from the fieldwork in order to get a foundation for the discussion. The workshop resulted in several sketches and a mock-up.

Work Practice in Haemodialysis Treatment

This section of the report will describe the dialysis treatment as it occurs at the dialysis department in Karlskrona. A real case is described in order to give a picture of what happens during a dialysis treatment at the hospital. After that, dialysis quality and how it is maintained at the department will be discussed. Three events from the case will then be further discussed and analysed since they appear to be interesting for the future design. Finally we present implications for design that were concluded from the analysis.

A Real Case

We videotaped a 5-hour dialysis treatment in order to get a picture of what happens. The patient receiving treatment was representative for the type of patients who would use Drop-In dialysis. He usually did not have many alarms, which the nurses describe as a calm patient. Also, he took active part in his treatment, preparing the machine and running machine self tests, which is required in remote haemodialysis.

(1.30 PM) *The patient Martin arrives and starts with a coffee break. The other patients are arriving one by one.*

(2:00 PM) *Martin weighs himself and then enters the dialysis room to prepare his machine. The room has six beds and patients occupy today totally five. Three nurses are preparing the machines for the patients. The nurses are Tom, Ellen and Betty. Betty is responsible for Martin and another patient Bengt, whose bed is placed next to Martin's. Martin is the only one today to prepare his own machine. Martin feels more in control of his disease if he can take active part in his treatment. He starts unpacking tubes and attaching them onto the machine. He attaches them swiftly since he is quite experienced. Betty is finished with preparing Bengt's machine and goes for a short coffee break. When all the tubes are connected to the machine, Martin initiates the machine's self test. This is done in several steps in order to test different parts of the machine, for example the different blood circuits. Martin changes some parameters on the machine screen to suit his treatment. While the machine is running the tests, Martin is walking around in the room chatting briefly with the other patients. The topics concern transplants and health. After a while he returns to his bed and grabs the paper machine record to write down the required values from the machine. This documentation is done every time the machine is tested. Betty returns from her coffee break and begins to start Bengt's treatment.*

(2:30 PM) The machine tests are successfully completed and Martin puts the machine record back on top of the machine and sits down in the armchair. He watches TV while waiting for the nurse Betty to assist him in the start-up.

(2:40 PM) Betty experiences a problem with the start-up of Bengt and asks another nurse to assist her. They agree on waiting a little while with Bengt's start-up. Betty walks over to

Martin to assist him. She gives him disinfectant on a cotton pad and asks him to clean his arm while she prepares the needles and tubes. The start-up begins with insertion of needles into an artery vein and a venous vein in Martin's right arm. Then, Betty connects the artery tube from the machine to the artery needle. While the artery tube is filled with blood she sets some parameters on the machine screen. She asks Martin what blood flow rate they should have this time and he suggests 300 ml/min. They also agree on the UF-rate. The aim is to remove three litres of fluid this time. Betty then connects the venous tube from the machine to the venous needle. She observes the machine to assure everything is working out fine. Martin looks at the needle in his arm and reacts on its behaviour. Betty examines the needle. Martin says that it is ok. Betty agrees and says that the values on the machine look fine. Betty walks over to Bengt.

(3:00 PM) *Betty returns to Martin to tape the needle onto his arm. She puts the blood pressure gauge on his left arm. While waiting for the measure, she activates the machine's alarm so it is visible both in the room and in the corridor. The blood pressure is a little bit high but still ok. Betty takes notes in the medical record. She asks Martin about his weight. When she is finished she returns to Bengt.*

(3:05 PM) Betty checks the values in the machine record, which Martin filled in earlier. She looks in the journal and on the machine screen. Then she returns to Bengt.

(3:25 PM) Tom walks over to Martin in order to check the medical record. He starts writing down some notes but is interrupted by an alarm at one of his patients. He leaves to take care of the patient. A few minutes later Tom returns and continues to take notes in the medical record. The temperature setting is different than normal, so he asks Martin if he normally have 36 C. They discuss the reason and conclude that Betty must have lowered it. Tom leaves to take care of other patients. Martin continues to watch TV.

(4:00 PM) *Martin asks Tom, who is working in the room, for a bit of tape to fix the tubes to the chair. Tom fetches the tape from his pocket and helps Martin. Then he leaves. Five minutes later Tom returns to Martin and takes notes in the medical record. He takes the newspaper on the serving trolley and leaves. Martin watches TV.*

(4:40 PM) Tom gives Martin a newspaper to read. Ten minutes later another nurse comes in and serves the patients a meal. She chats and laugh with Martin about life in general while serving him. When she is about to leave the room, Bengt asks her to help him moving the machine so he can sit and eat. She jokes friendly and helps him.

Figure 7. *Martin watches TV.*

(5:10 PM) *Betty returns to fill in Martin's medical record. He asks her how the treatment is going and she replies that it's looking good. She takes the dishes from the meal and leaves. Martin continues to watch TV.*

(5:55 PM) another nurse enters the room and asks Martin if he would like to pay his medicine. They joke and laugh while Martin is making his payment. The nurse leaves and Martin continues to watch TV.

(6:00 PM) *Martin is looking a bit tired still watching TV. Suddenly his machine gives an alarm. Martin resets the machine and Tom arrives. They are puzzled, since Martin usually doesn't have any alarms, and discuss the reasons for the alarm. They decide to measure Martin's blood pressure. Tom goes away to another patient for a couple of minutes and then returns to look at the blood pressure, which turns out to be fine. He leaves to help another patient, but soon returns again. He asks Martin what the blood pressure was again and writes the value into the medical record.*

(6:05 PM) Another nurse enters the room and asks the patients if they would like to have coffee. Martin nods. Shortly after, the nurse serves the coffee and a bun. Martin drinks his coffee and watches TV.

(6:40) Betty reappears and asks Martin how it is going. Martin replies that is going fine. Betty takes notes in the medical record. She asks Martin if his arm feels good and he nods. She then goes over to Bengt and writes in his medical record. Betty leaves the room.

(7:00 PM) *Another nurse gives a telephone to Martin. Someone called for him. Martin talks on the phone for about 15 minutes and then continues to watch TV.*

(7:40 PM) Betty returns and fetches Martin's coffee cup and the telephone. They decide to close the treatment. Betty leaves the room for a moment. When she returns she starts unpacking tools required for closing the treatment.

(8:00 PM) *Martin's treatment is finished and he is ready to leave.*

Quality in Dialysis Care

One of the most discussed topics at the department is the quality of the treatments received by the patients. The nurses' vision is to give good dialysis. During our fieldwork we have looked closer at the notion of quality. We recon that it is a tacit concept with a wide range of aspects, which all play important roles in the process of judging the quality of dialysis treatment. It is tacit because it does not only comprise measurable factors like clinical results, but also judgements of the patient's ability to live a normal life.

In close connection with the concept of quality stands the environment of the department. The department is a hybrid of being at home and being at a hospital. As a result both the nurses and patients know quite a lot of each other, turning themselves into individuals rather

than just patients and nurses. This knowledge is also transferred into the different aspects of quality.

The clinical result is the measurable aspect of quality. When you arrive at the field as a researcher, you are almost immediately introduced to it. Quality of clinical result consists of whether the designated dry weight is achieved or not. The dry weight is the weight a patient should have after a treatment is received. It is calculated based on the weight, intake of food during the treatment, desired amount of fluid to be removed. The dry weight is therefore a measure of if the correct amount of fluid and substances has been removed. It is part of the department's policy that defines the ideal treatment. Based on Suchman's book on plans and situated actions many contemporary research articles has been spent on the CSCW discourse on the conflicts between formal procedure and actions as they unfold in situ (Suchman, 1987, Robinson, 1993, Bowers and Button, 1995). At the dialysis department this clash is quite evident in the notion of quality. The formal clinical aspect is the one noted and cared for by the administration but there are other aspects that make up the notion of quality. These are quite tacit but important for the nurses both in balancing the work between them and judging the chain of actions need to be taken in different situations.

Another concern in dialysis care is the well being of the patients. When the nature of the sickness requires continuous visits several times a week the patients become faces with a history to the nurses. The nurses talk with the patients before and after the treatment, they judge how they behave and talk to create an abstract representation for themselves over the patient's view of quality. To further strengthen the knowledge of each patient they assign responsibilities. Each nurse is responsible for a couple of patients during a limited time period. During this time period she builds up knowledge of the patient, how he reacts under different conditions, what he expects socially while at the department etc. The nurses also gets insight in the patient's quality of life concerning the time spent outside the hospital, the general status and history of the patient's private life, through on the talks they have with the patients.

A quite observable but informal aspect of quality is the services received by patients during their treatments. To large extent the work carried out by nurses is supplying the patients with newspaper, food, extra pillows and all sorts of things. This is for the well being during the treatment, so the patients feel confidence and secure. In turn it may have affect on the number of alarms and muscle cramps, which is disturbing during treatment. In this sense the amount of alarms is a measure of quality.

The Enmeshed Quality

At first the quality is considered to be the actual clinical aspect, while in reality it is something that is obtained by juxtaposition of the aspects we have discussed above and possible more fine grained values and aspects yet to be uncovered.

There are no clear borders between aspects of quality. They are constructed from the mutual understanding of the praxis, the visibility of each other's action, the knowledge of

patient history. It is important to recognise the environment at the department to understand how quality is maintained. Within the Drop-In vision quality is considered to be one of the main factors to improve through different means. The question to pose is how the notion of quality will change when it shifts from being established at the department to be mediated through a medium. It is likely that the focus will shift to supervise clinical results, loosing knowledge of patients' quality of life, since the social encounters at the department will disappear. To understand how nurses create their understanding of patients today, we have looked at how they maintain quality during treatment.

How is Quality Maintained?

As described, quality of dialysis comprises several aspects. The nurses supervise these aspects in different ways. The clinical result is measured by the machine and routinely noted by nurses in the paper medical records and machine records. Awareness of the quality of treatment and the patient's well being is achieved by the nurse working in the same room as the patient. The encounters at the department, for example start-up, provides for conversation, which is an important way of getting to know the patient. In this section the artefacts and routines used during treatment will be discussed closer.

Dialysis Machine

The dialysis machine's basic functions are to take care of the circulation of blood and dialysate fluid through the dialysator. It also has safety functions that supervise and control all processes to make the treatment safe. For example, the blood pressure in the machine is monitored in order to detect disconnections and choking, which can be caused by knots on tubes or coagulation. If changes in pressure exceed the defined boundaries an alarm goes off. Artery alarms are the most common and are often caused by the patient's movements, which makes the needle suck to the walls of the vein and hinder the blood low. The nurse adjusting the needle a bit deals with these problems. The machine also detects if there is air in the blood or a blood leak. If there is, an alarm goes off, the pump stops and the patient is disconnected from the system.

On the machine there is a touch screen with which the nurse can make settings regarding the blood flow, dialysate fluid temperature etc, to a software that controls the machine. The GUI displayed on the screen also gives feedback on alarms.

Machine record

Each machine has its own machine paper journal, where the nurses write down the machine related settings, accomplished tests and reported problems. The machine record contains the machines history and serves as an important artefact in tracing problems.

Medical record and Hourly Note-Taking

In the patient paper journal, information about medicines and values from each treatment are gathered. The nurses also note values every hour during a treatment. This is done in order to

read how the dialysis proceeds and to anticipate complications, for example, falls in blood pressure or clotting of the dialysator. These figures are also of interest when the patient comes on checkups or has other contact with the department.

Serving Food and Medicines

Throughout the treatment patients have contact with nurses at several times as the nurses serve meals or maybe delivers medicine. The routines have beside their obvious purposes, also the benefit of social interaction. Often the nurses and patients chat during these encounters, as described in the real case, which helps forming an opinion about the patient's well being. The encounters also make it possible to see the patient, which also indicates his well being. For example, the appetite is an indication of the patient's well being.

Awareness by Being in the Same Room

There are a number of patients receiving dialysis in each room. The physical design of the department thus matters quite much, since it is laid out as two main treatment rooms. These rooms create the possibilities of at-a-glance overview for both nurses and patients. For the nurses it creates opportunities to see the status of patients and based on their knowledge of the patients history intervene if needed. Patients in their turn may request the attention of a nurse when occasions are given. These occasions are themselves constituted by the accountability of the nurses' actions.

Three Cases and Their Relation to Quality and Counselling

We have found three cases in the scenario that we find particularly interesting from a quality and counselling perspective. These cases show what kind of problems arise, how they are solved, what resources are used and division of labour.

The Needle Looks Strange

This case occurs in the start-up of the treatment. The nurse has connected the tubes to the patient and is making some settings on the machine. The nurse and the patient are discussing about when the taxi should pick up the patient when the patient discovers that the needle looks strange.

N= the nurse, P= the patient

	*P: Darn... [looks at the needle]*
	*N takes a look at the needle and taps on it.* *P: It's not that bad, as long as it doesn't look like that the whole treatment.*
	*N: No. Let's hope it alerts us. [presses some buttons on the machine screen]* *N: It looks perfectly fine. Let's run it on 300.* *N removes the bag with fluid and goes to another patient.*

This case shows us the benefits of physical interaction. The needle seems to be twisting which is not desirable. In order to form an opinion the nurse looks at the needle and taps on it. In this kind of problems, the physical interaction is necessary. As we see it, it is a challenge to find a good substitute for the direct physical manipulation as the drop-in vision suggests.

Video has been used and evaluated within the dialysis project and in other research articles (Sanchez Svensson, 2000, Holland and Stornetta, 1992, Cadiz et al, 2000). These articles all points in one direction. Videoconference equipment could partially assist in getting a picture

of the needle but still it does not support the kind of notion that tangible interaction supplies. It could be argued that it is simply a question of resolution in the videoconference equipment etc (Bittan, 1993), an argument that only the future could resolve true or false. It is our opinion although that the physical interaction provides a tactile inspection of the needle, a feeling for the material, as well as an at-a-glance of blood flow etc in situ. To us it seems as we make sense of the world with both of this aspects in the situation, which would discard the video as a substitute. This does not exclude video as an alternative; it merely suggests that video provides an alternative view, which will provide a different set of knowledge and demand new roles.

Interestingly, the patient alerts the nurse about the needle but when she takes a look at it he suggest that the needle does not have to be a problem. This indicates that the patient form his own opinion and can make own predictions. It is likely that he merely wants to assure that the nurse knows about the potential problem in case of further complications. This is an example on how the work practice evolves. The more experienced the patients becomes he generates more knowledge about himself and his sickness. He understands more of the actions taken by nurse. The environment creates the accountability of patients and nurses actions.

The nurse is also making the settings for the treatment on the machine, and the position of the needle and its rotation is vital to the settings of the treatment, i.e. the blood flow rate. If the needle is properly inserted the speed can be higher, which generally is a better dialysis. In the remote dialysis situation, the patient will make these settings himself and make own decisions. Still, for the nurse in the advice-giving role, it is important to know about such details. It is a foundation for interpreting alarms and solving problems in different situations.

The machine is also an important resource for both the patient and the nurse in the case. The nurse looks at the machine to get information about the status of the treatment. From the figures on the machine she interprets that the treatment is working fine. Based on the physical inspection, the patient's remark and the machine's display, she decides not to take any action. This is an example of an interesting aspect of how problems are dealt with. In this case the problem is only potential for now. The important part is that both the nurse and the patient acknowledge the situation in case of further complications. Much of the work is about locating potential problems and preventing them.

This example shows how situations are dealt with today at the department, how the physical and social environment creates the common understanding of actions. It also shows how this understanding creates overview of potential problems, so actions can be taken to prevent them. This is also an example of situations that could be hard to create with two different geographical locations. The discussion that appears in the example around an alarm probably won't exist over distance due to the changed responsibilities. However the example also shows how it is used to pin point potential problems, which will be desirable to maintain and improve the quality for remote patients.

Tom Recognises an Odd Temperature

Half an hour into the treatment, a second nurse makes notes in the medical record. He notices that the temperature setting is unusual.

N= the nurse, P= the patient

	Nurse2 returns and starts filling in the medical record again. *Nurse2: Temp 36 is what you normally have?* *P: What?* *Nurse2: You have Temp 36, right?* *P: It should be 36,5…* *Nurse2: mmm… There might have been patients before who had 36.* *P: I checked it when I made the settings.* *Nurse2: Did you?* *P: Did I really misread that much...* *Nurse2: Nah..* *P: Or does it go back by itself?* *Nurse2: It can be set.* *P: I might have misread...* *Nurse2: No but when… when you have high blood pressure it might help to lower it.*
	Nurse 2 checks the machine record.

	*P: Did it say 36,5?* *Nurse2: Yes it did.* *P: Maybe she lowered it..* *Nurse2: Yeah..* *P: Because the blood pressure was higher than usual.* *Nurse2: Yes it was, that's right.* *P: That's maybe why she lowered it..* *Nurse2 moves away.*

There are two nurses actively working on the same patient during the treatment. One is main responsible and the second is assisting since he has his patients in the same room. At the department, the nurses always double-check the medical record with the machine settings to make sure they are correct. The second nurse reacts on the temperature setting since it is unusual and asks the patient if it normal for him. In the dialog the nurse and the patient together track the setting. First the patient replies that he did not intend to set that temperature but he might have misread the screen. The nurse suggests that there may have been patients before with a lower temperature because it helps when the blood pressure is high. He checks the machine record where the temperature is written down at each treatment and discovers that it has not been that low. The patient recalls that his blood pressure was high and suggests that it must have been the other nurse who lowered the temperature.

The case shows how the information from the machine screen and the machine record, combined with the patient's knowledge of his own treatment and the nurse's professional knowledge, are used to recreate the course of actions taken to find the reason for the low temperature. By tracing the information and settings through the available sources, he is able to recreate a course if action take by another nurse, simply cause it makes sense to act in that way. The actions taken are made accountable.

The example also gives a glimpse of how nurses co-ordinate their work with a case over time. A nurse cannot change a setting without first finding out if there was a good reason for it. This case could be seen as a metaphor for how coordination of work could be integrated into a piece of software for remote haemodialysis support at the department. The discussion held between nurse and patient and the way information resource are used could be used to create a user scenario.

In remote dialysis, which emphasises advice giving, the recalling of the treatment's history will be important to be able to form an opinion about the situation. Even though the reason for this situation might never occur, since the patient will make the settings himself and thus know the reason for them, the way of recalling the treatment's history is interesting. The nurse and the patient must be able to share their knowledge and to have access to information

resources equivalent to the machine record and the display. The machine record tells about the history of the machine's settings and the display tells the current situation. In remote dialysis, the patient will have access to the machine display and the machine record. The question is what information is necessary to display to the nurse. The case implies that the current machine settings are of interest to the nurse in order to suggest an action, for example that it is possible to lower the temperature in order to balance the blood pressure. In this case the machine record is essential to complete the task but it does not necessarily have to be the nurse who uses it.

The Alarm

During the last hour of the treatment, an alarm goes off. A nurse comes to help the patient. Together they decide what actions to take.

N= the nurse, P= the patient

	A sound alarm goes off. P looks on the machine and looks on his arm.
	Nurse2 comes and looks at the machine. P turns off the alarm. *P: Why? Did I move?* *Nurse2: Did you?* *P: I don't know..*

	Nurse2 looks and fiddles with the needle.. *P: But it looks fine. Yes it might have been.. maybe it is a little* [points to his arm] Nurse2: [mumbling] P: It has never been an alarm before since we started using [mumbling] [They laugh] P: There has never been any. This is the first alarm since we started using this one [P points to his arm again] Nurse2: Have you measured the blood pressure? P: Yes, it was quit high so maybe we should do it again and see how it's going.
	Nurse2 puts on the blood pressure measurer on P and presses a couple of buttons on the machine. Nurse2 leaves.

The first thing to notice in this case is how skilled the patient is. As soon as he recognise an alarm he throws a glance at the screen and the one on his arm. Through these two moments he creates and idea of the alarm and why the machine triggered it. In the second phase of handling the alarm a nurse enters the case. Several interesting things happen in this phase.

First there is a shift of roles. As soon as the nurse enters and start to examine the cause of the alarm on the machine the patient enters a passive role. He has a formed an idea and judged the severity of the alarm, but he doesn't tell the nurse right away. This is probably a cause of the professional trust explored in different books (Schön, 1996). As he is a patient at the department he is a receiver of professional health care, hence he assumes that the nurse is more skilled and professional then himself. Instead he describes his point of view through questions posed to the nurse. Thereby keeping the authority given for the hospital as an environment but still informing the nurse on possible future course of actions.

Enquiring this case further, we find the usage of mutual awareness through the dialog. To understand the alarm and how acute it is both the patient and nurse visualize their engagement and knowledge of the situation through body language and linguistic utterances. It also suggests how a normal alarm is treated at the department, a situation that not will appear in the same way over a distance, since only the acute and unattended alarms will be in focus for the nurses. But it also unfolds how alarms are treated in a time perspective. In the time perspective it is the amount of alarms and their placement in time to some degree refers to the quality of a dialysis treatment and the severity of new alarms. This perspective is interesting for the drop-in vision and how visualizing the flow of alarm as an at-a-glance view of how well a treatment is proceeding.

Summing Up

The workplace studies have revealed different aspects of quality in haemodialysis, ranging from clinical results, well being during treatment and overall quality of life. These aspects are today supervised in different ways. While the quality of clinical result is measured by the machine and in the nurse's routines, the other aspects are more tacit. The nurses develop an understanding about the patient when they meet in the hospital. The routines like the hourly note taking or the start-up and closing of treatment provide for natural encounters where the nurse gets information about the patient's fitness and life. A personal relation between the nurse and the patient is established. This way the nurse also has knowledge of the patient's history and behaviour, which is valuable when forming an opinion in specific situations.

The studies also show that we initially overestimated the importance of alarms for quality assurance. The patients who would conduct remote haemodialysis are likely to have few alarms, just as the patient observed in the study. Also, the alarms that occurred were not serious and could be handled by the patient himself. This matches the results reported from the Canadian DNHD project. However, the seriousness of alarms is related to their frequency. Frequent alarms indicate that something is out of the ordinary and need attention.

We have also observed that the nurses' coordination of work depends on awareness of their colleagues' activities. They can then adjust their work to each other when they need help. There are no formal procedures for assisting each other; it is an ad hoc activity, based on the demands of the situation at hand. They coordinate their work so that one nurse can go on a break, do administrative tasks or deal with unexpected events. Also the patients seem to have respect for the nurses' work. In our case, we experienced that the patient took contact with the nurse when the nurse was actively involved in his case. The accountability of nurses' and patients' actions is evidently important to create a smooth cooperation between patient and nurse.

The Drop-In Visions' New Demands

The Drop-In vision implies foundational changes the existing work practice. It is manifested that the quality of treatment has to be the same or better in if the vision is to be realised. There are many aspects that promote that the quality will be better, since the patient can decide time and length of treatment allowing for a more flexible life etc. But, the means of supervising the quality will be reduced. The clinical results of treatment can easily be supervised through technology. It is the other aspects of quality that are related to the nurse's personal knowledge of a patient that will step into the shadow.

The vision also states that patients will be responsible for their own treatment. A shift of roles is thereby created. The nurse's role will be counselling rather than today's nursing. This means that the supervision mainly will consist of keeping an eye on the treatment rather than solving problems and handling alarms.

Implications for Design

From our research we have established a few design principles. These principles are thought of as guidelines in our design process. They have as purpose to highlight aspects of the current work that we could use to design tools for the remote haemodialysis.

Support Different Aspects of Quality

As noted, the clinical result of quality is likely to put the other aspects of quality in the shadow when supervising the patients remotely. We find it important not to suppress one over the other. The values showed on the machine display today, must be visible to the supervisor to be able to judge the clinical result. The patients that would conduct remote dialysis are calm and autonomous patients, which mean that the nurses most likely won't have to interfere very often.

The clinical aspect of quality is easily supported through displaying the machine values from the patient side. To support the other aspects it is important to maintain a relation between the nurse and patient.

Support a Relation Between Nurses and Patients.

It is our opinion that the same rich understanding of the patient is impossible to create without face-to-face encounters. Whether or not that kind of rich understanding is necessary we decided not to investigate further. Still, the system can support a relation between nurses and patients through offering easy communication combined with the possibility to coordinate their moments of communication through awareness and accountability of each other. Nurses and patients would then be able to create their own routines for contact. Also, by distinctly representing each patient the nurse is able to quickly use the knowledge of that patient.

Support Awareness

Awareness is crucial for the nurses' supervision of patients. They must be aware of which patients are having dialysis remotely and if the treatment is satisfying. If serious situations arise in a treatment the nurses' attention must be drawn towards that patient.

Because the nurses are carrying out many tasks and the supervision is only part of that, the awareness should be achieved automatically without demanding full attention in order to get information. Since the nurses very frequently move through the corridor between the rooms, it makes sense to place the system there.

To support counselling and communication the patient and nurse must be aware of each other. As shown in the case study, the patient takes contact with the nurse when he understands that she is involved in his treatment, which is something that can be mediated by the system. In the same way the nurse should be aware of whether the patient wants to talk.

In order to coordinate the counselling with the work at the department the accountability of action between nurses must be supported.

Support Accountability of Action Between Nurses

As we see it accountability of action is today much due to the physical environment and artefacts used, which makes the actions visible at-a-glance. Nurses and patients can see what the others are doing for example because they interact with a machine or are having conversation with someone. By knowing the dialysis practice they can interpret what is going on. In the same way, tasks performed with the system should be visible for co-workers to allow for smooth coordination with other tasks.

Design of Conceptual Prototypes

During the project two conceptual ideas has evolved as solutions to specific problems in the drop-in vision, the Mushroom and the Dialysishouse. The Mushroom was a legacy from a previous project we hade been involved with. It was discarded early in the project in favour for the Dialysishouse. Overall the Mushroom had significant impact on the Dialysishouse and has to be described below.

The Mushroom

The Mushroom was our original design idea of a tangible IT-tool for the nurses. The intent was to supply the nurses with a supervision tool of remote patients based on alarms (Dahlström, 2001). The background for this tool was the previous studies of the nurses work practice that had been conducted with a focus on cooping alarms (Tap, 2001).

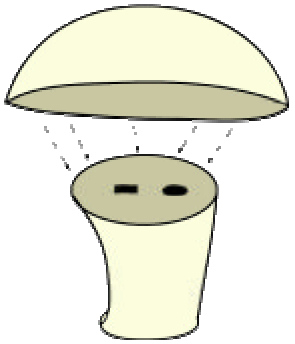

Figure 8. *Sketch of the Mushroom.*

The tool was a physical figure that resembled a Mushroom. It consisted of two parts, a cap and a body. The cap represented a patient and the body represented a physical location. By combining different caps and bodies, it's possible to create different treatment sessions depending on the patient and its location. It was designed to fit into one hand so the user would be able to carry it as they moved around the department. The Mushroom would normally be placed on a desk in the department corridor. As they stood there they visualized the amount of alarms that had passed during the represented session. When a new alarm appeared the Mushroom would change colour and alarm would be heard. It was then possible for the nurses to establish an audio link and resolve the situation by picking up the Mushroom. If more information was needed it was possible to move the Mushroom to another context, such as videoconference or medical e-journals.

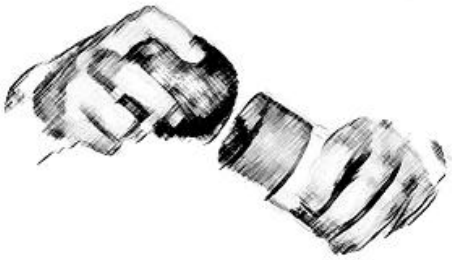

Figure 9. *Physical interaction with the Mushroom.*

The purpose of the design was to explore new ways to interact with computational technology for the nurses. Firstly by trying out a physical interaction when administrating remote treatment sessions instead of a traditional GUI. Inspiration was taken from the interaction style of the dialysis machines, for example, connecting tubes. By imitating this style, through making the Mushroom in two parts that would be connected, we believed that a homogeneous interaction style in the work practice could be achieved. By facilitating a physical figure we also wanted to explore how it would affect the visibility and coordination of workload between the nurses.

This design was developed as far as conceptual sketches and descriptions of what and how technology was to be used. When we learned more about the context of remote haemodialysis, we discarded the Mushroom concept.

The Mushroom supported both awareness and accountability of action between nurses through its physical properties. The problem that it solved was to alert the nurses when a patient had an alarm so that she immediately could respond. Thus it only partially supported the goal of this thesis, designing for accountability and awareness, but not the context.

As the work place studies showed, it was important to supervise alarms in case of emergency, but it would not be a frequent usage. Since the Mushroom was based on only showing alarms, we decided to start over with these new insights.

The Dialysishouse

The final prototype is based on the metaphor of a dollhouse. It consists of a house with a number of rooms, where a wooden sculpture, tagged with an electronic id representing the patient, can be placed. When a sculpture is placed in a room, the wall in that room displays an overview of the patient's treatment. If a patient requests for a chat the patient sculpture lights up. The nurse may then grab a headset, hanging on one the Dialysishouse walls, and speak to start a conversation with the patient.

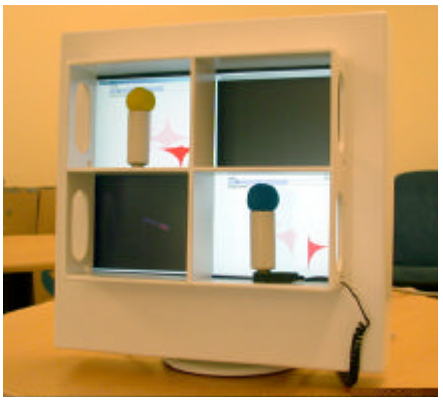

Figure 10. *The Dialysishouse prototype.*

The sculptures function as a physical index of the patients. The index is to be used in a variety of applications, such as e-journals or videoconference equipment. When a nurse wants to, for example, view a more precise data of a particular patient's machine, she moves his sculpture to a tablet connected to a PC displaying the machine UI, which is a computer application.

At the remote location, where the patient conducts his dialysis, another sculpture, a nurse sculpture, is placed on a tablet. The nurse sculpture represents the nurses at the department. Whenever a nurse is interacting with the patient's case, for example moving the patient sculpture to view detailed data, the nurse sculpture lights up. When a nurse opens an audio link with the patient, the patient hears the voice from the sculpture. To speak to the nurse, the patient can talk in direction of the sculpture.

The concept of the Dialysishouse consists of five major parts, the Dialysishouse, the sculptures, the proximity board, the nurse sculpture and a PC displaying the machine interface. Behind the scenes there also exists a server responsible for data storage and distributing events between different clients. In the prototype we have implemented the Dialysishouse, sculptures, proximity board and the server environment.

Each part, except the server environment, consists of a physical part and software. Below each part of the prototype will be explained more in detail, their construction and materials.

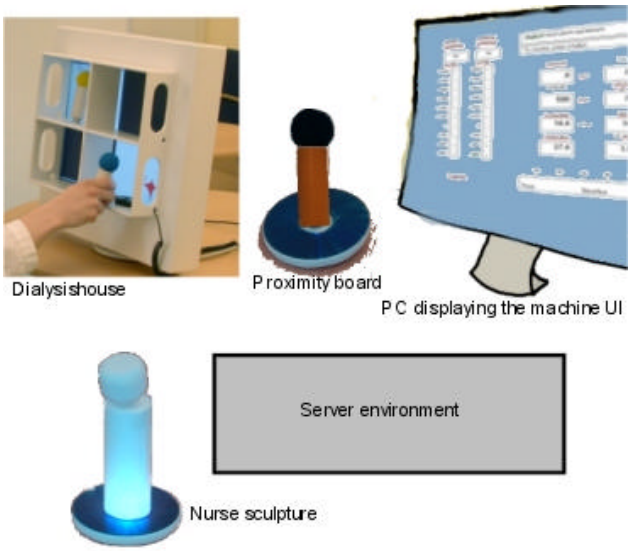

Figure 11. *The system's five parts.*

The Server Environment

The environment is a pure software component used to connect the other parts of the prototype. As it is a computational tool for nurses it needed to both to store and manipulate data as well of sending notices of different statuses to users and other computational devices. In the prototype a model for distributed event handling was needed, since an arbitrary amount of clients could be involved with a specific patient data, which all need to know about different changes. Since the prototype also was distributed over several clients it also needed some way to keep consistency in each patient's data.

The solution that best fitted those needs and the available resource was the Java Enterprise server JBoss. It is a server implementing some of the latest Java Enterprise standards as well as benefiting from being a free open source implementation. Leveraging on the java enterprise beans 2.0 standard and the java message service 1.1 standard implementations in JBoss, both problems were solved.

Designing and implementing a set of Container Managed Persistency (CMP) 2.0 Entity Java Beans solved the data management issue. Benefits of the beans are flexibility during development and deployment time, since the CMP 2.0 beans only defines what data and how the relate to each other and leaves the actual storage to be solved and implemented by CMP 2.0 enterprise servers. Around the entity beans a set of session beans was designed to protect the entity beans and increase the general response time of the system.

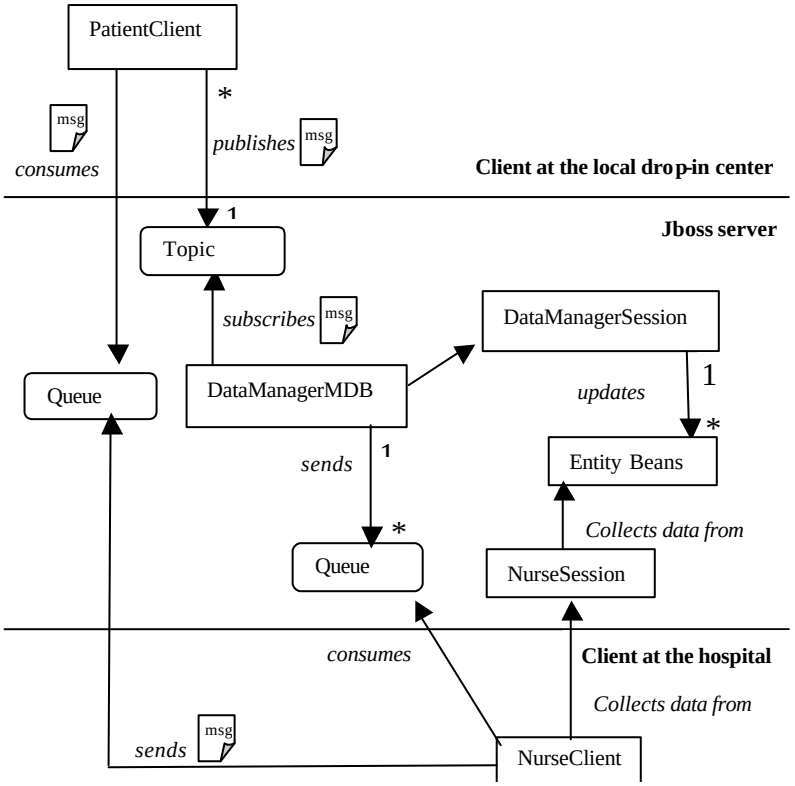

Figure 12. *Overview of the Java Enterprise solution using JMS for notification between the clients at the patient and nurse locations.*

To create a distributed event system we took advantage of the Java Messaging System, which also is implemented in the JBoss server. It creates possibilities for the server and clients to send and receive messages of different types regarding status changes. This approach is similar to how GUI usually is structured around an event-based model

On further advantage to use a Java Enterprise Server is the possibility to easily construct a web based administration client or even completely web based clients instead of those we have developed in this project. This could be source for further evaluation of different types of interaction styles within this specific domain.

The Dialysishouse

The Dialysishouse is the hub of the prototype. It is a collection of rooms that represents all remote locations that are available to patients for dialysis treatment. The intention is to supply an overview of active remote treatments. When a new treatment session is about to start at the department, one of the nurses checks who and where someone has scheduled for treatment. She places the sculptures representing that specific patient in a room. When the patient later on starts his treatment the room in Dialysishouse is lit up to symbolise it. The information is visualised on the back wall as a progressbar and three graphical figures. The progressbar shows how much of the treatment is completed. It also displays the alarms at the times they occurred. The graphical figures are shaped like a star, where each edge represents a factor

such as venous pressure. One figure represents the current values and the other two the past two treatments at the corresponding time (see figure 13).

The Dialysishouse is mainly constructed of wood. The visualisation of values in each room is displayed on a TFT screen that functions as wall. The TFT screen is connected to a laptop, which generates the visualisation. In each room there is an IButton probe connected to the laptop. The sculptures are placed onto the probes and allows for the software to recognise the sculpture.

The Dialysishouse also consists of a Java application running on the laptop. The application connects to the server described earlier and retrieves what message queues it should listen to for status changes. When the application is notified of a change in status it retrieves the current data related to active patients in the Dialysishouse, from the server.

The Sculptures

The sculptures representing the patients are modelled in Styrofoam. They are shaped to resemble humans but yet only consist of a few simple shapes. At the base of the sculpture an IButton is attached in a countersink. The countersink works as a socket when the sculpture is placed on an IButton probe in one of the Dialysishouse rooms or at a proximity board. The sculptures functions as an index to data about a patient.

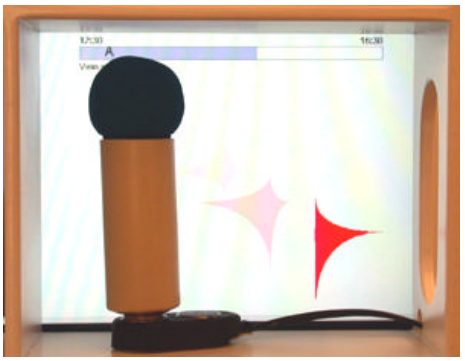

Figure 13. *The sculpture represents the patient.*

The Proximity Board

The proximity board is a designated area where the sculptures can be placed. Proximity boards are connected to different types of equipment that can benefit from using the sculptures as index to information. This construction is simply a computational enriched board made out of wood. In the middle, an IButton is mounted as a socket for the sculptures. The floor in each room in the Dialysishouse is an integrated proximity board. Other examples of where the usage of the proximity board would prove beneficial are for example videoconferences and medical e-journals.

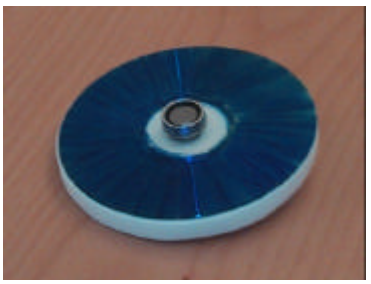

Figure 14. *Proximity board.*

PC Displaying the Machine Interface

If the nurses should be able to give advices to remote patients they need to both see an overview of the treatment and have the possibility to closely examine data relating to treatment session. The idea is to solve this through the usage of a screen placed on the wall with a proximity board beside it. The proximity board is connected to a piece of software that displays a proxy for the remote dialysis machines UI on the screen. The screen UI supports

the navigation used today by the nurses on the screens available. The PC displaying the machine UI only supports navigation and looking on the data, hence it's not possible for the nurse to change settings on the remote machine since it is a task assigned to the patient in the drop-in vision.

In the case of detailed information about a patient and her treatment, the board is connected to a screen acting as a proxy for the machine's UI.

The Nurse Sculpture

The nurse presence tool consists of a sculpture, shaped to remind of a human, representing nurses. The sculpture does not contain an electronic id like the patient sculptures at the department, since it should represent any nurse. It is placed on a board, with small diodes surrounding the sculptures' base. Inside the board there is an embedded computer, which steers the diodes and the communication with the server. To call on a nurse, the patient may press the head of the sculpture, which sends a message to the Dialysishouse at the department. When a nurse interacts with patient data through the physical index, the nurse sculpture is illuminated by the diodes.

Figure 15. *Nurse sculpture.*

The Findings Revisited

In the workplace study we formulated four implications for design as guidelines. These are present in different ways in the design of the prototype. The design's relation to the implications is discussed in this section.

Supporting Different Aspects of Quality

Supervision of clinical result of treatment is supported with the overview on the walls in the Dialysishouse and the PC displaying the machine UI. The aim of the overview is to give a brief understanding of the treatment; the time elapsed, alarms and clinical factors. In the work practice at the department, this overview is achieved by a negotiation with the patient, starting up the treatment, glancing at the machine, etc. The nurses are looking for changes in the course of the treatment in order to anticipate problems. It is our intent that the overview of the clinical factors, in the shape of a star, is to visualise changes. The visualisation of the past two treatments provides a historicity for the nurses to judge what is normal. In the prototype we chose to represent the clinical factors artery and venous blood pressure, UF rate and blood flow rate. These factors are merely our suggestions, but far from absolute. The nurses should decide which factors they would like in the overview. The work place analysis shows that the machine and its data are important in problem solving and supervising the clinical results. Therefore the PC displaying the machine UI with detailed patient's data, corresponding to the data in the patient's dialysis machine software, should be available.

The number of alarms tells whether the patient receives an uncomplicated and calm treatment. The overview mediates this with a progress bar with alarms marked out at the time they occurred. It seems less important to present the number of alarms, than providing a possibility to interpret their relation in time. For example, if there are several alarms in the beginning, it can be assumed that it has something to do with the start up. A timescale provides a good presentation of the alarms in time. As the case study and the experiences from the Nocturnal Haemodialysis project show, alarms are infrequent with patients that are suitable for remote dialysis. The patient should manage the alarms themselves. The alarms mediated by the Dialysishouse are non-intrusive as default, since they appear only as icons. But if they are not taken care of by the patient, eventually a sound alarm will go off in the existing alarm system at the department. The procedure is similar to the routines in the Nocturnal Haemodialysis project, where the observer waits two minutes to see if the patient takes care of the alarm before calling him.

Supporting a Relation Between Nurse and Patient

According to the case study, the patient mainly speaks with the nurses when they are actively doing something with his treatment, such as writing in the journal or serving food etc. This is an indication that the patient has respect of the nurses working with other tasks and not wanting to disturb. When nurses are actively involved with the patient's case, it is a convenient situation for asking questions. Accountability and awareness of each other's actions is essential for coordinating the interactions between nurses and patients. The moments of conversation are useful to keep in drop-in dialysis and are reflected in our design. By indicating to the patient when a nurse is actively involved with his case, we want to make the nurse's action accountable to the patient so as to provide for these kinds of convenient situations.

The patient is able to indicate in a non-intrusive way, that he wishes to speak with a nurse. Since the patient cannot see what the nurses are doing, except when they are looking at his case, and interpret their course of actions, he cannot adapt the times of his requests to suit their work as well as he can in the hospital. Therefore the call for attention is silent and non-intrusive but still notable. The nurse knows that the patient wants something and is able to take it into account when planning their current work.

The nurse may also start a conversation with the patient at any time. The overview of the treatment may trig the nurse to contact a patient. For example, if patient data looks unusual as described in case 2, the nurse is able to ask the patient about it through an audio link.

The intention is that nurses and patients should be able to create their own routines for contact. An easy tool for communication, designed to provide for accountability and awareness of each other's situation, would support the emerging of informal conversations, which is important for the relation between patient and nurse.

Supporting Awareness

The general idea is to give the nurses an at-a-glance overview of the current status of the remote dialysis treatment, while carrying out their tasks at the department. The at-a-glance overview will provide a peripheral awareness of the patients. This corresponds to the way nurses monitor in-door patients. Even though nurses are not always actively involved with a patient, most of the time there is someone who has an awareness of the patient since they are working in the same room with other patients as shown in the case study.

By placing the Dialysishouse in the corridor through which nurses frequently move on their way to different rooms, awareness is supported. When the nurses pass the Dialysishouse they will notice at-a-glance who is having remote haemodialysis since each sculpture represents one particular patient. Similarly to the previously mentioned keyrack, the Dialysishouse provides an overview of the remote patients from the distance within a room. When moving closer, brief information about the status of the treatment is displayed on the wall in the Dialysishouse room. This corresponds to the way nurses are aware of patients at the department. They know which patients are receiving dialysis since they are in the same room. If they need to know more information about the patient, they look closer on the screen or talk to the patient.

We have chosen to have each patient represented by one particular sculpture so that the nurses may use their knowledge about the patient's history and situation in order to decide a proper action. If a nurse is aware of that, for example, Kent is having his treatment, she knows that he has had problems with a high blood pressure and therefore she can choose to keep an eye on him. The sculpture in the Dialysishouse also conveys if the patient wants attention. The sculpture is illuminated by a light bulb, which lights up when the patient wishes to speak with a nurse. Light is visible from a distance and also gets attention without being intrusive like for example sound.

We believe the Dialysishouse opens up possibilities for the nurses to configure the system suitable to their practice. They may place the house at a proper place, which makes sense to them. Perhaps it is not the corridor, but one of the rooms with patients that is suitable for achieving awareness. Also, they may arrange the sculptures between the rooms in the Dialysishouse in ways that would convey additional information. For example, arranging the sculptures according to distance of patient would provide a spatial sense of where in the region treatments are going on.

Supporting accountability between nurses

In today's work practice at the department, it is visible between the nurses, who is working with which patient and what they are doing. This is much due to the fact that the patients are present and different physical artefacts are used for each action. The machine, the tubes, the paper journals are all physical artefacts that take up space in the world and are recognisable through their different shapes. This reminds of the Nuclear Power Plant example where the operators could interpret each other's actions since they had to walk over to a certain part of

the system to perform a specific task. The nurses can help each other out, and give each other advice, based on their knowledge of each other's actions.

The system has been designed to contribute to accountability of action between nurses in several ways. First of all, it should be placed in a busy area such as the corridor, which nurses frequently pass through. Thereby it will be visible between the nurses, who takes action on which patient's case and also the context of the action, for example what happened before or after. Also conversations can be overheard when passing by. It allows for building knowledge of previous events, which helps interpreting actions, and predicting or deciding the subsequent.

Furthermore, the sculptures are physical objects that can be grasped. The overall system is physically distributed into different devices for a specific task, such as the PC displaying the machine UI and the Dialysishouse. The distribution implies that the interaction becomes observable. In order to get more information about a particular patient on the PC displaying the machine UI, the corresponding sculpture must be taken out from the Dialysishouse and put onto the PC's proximity board. The interaction with the Dialysishouse is thereby more visible, compared to clicking on a mouse on a PC. The interaction conveys which patient is the subject and what the action is (either looking at the machine UI or starting a video conference). Since nurses would have knowledge of the functions of each device, the action would be interpretable. If the supervision artefact would be a piece of software instead, it would not be visible which patient the nurse is concerned with or what action she was taking. The following scenario illustrates how the design supports accountability:

Nurse Tom enters the corridor. He is looking for nurse Betty because he wants to discuss Bertil's estimated dry weight. As he walks out into the corridor he sees Betty standing by the PC displaying the machine UI, where Martin's sculpture is placed, writing into a journal. In the same moment as he decides to approach her, she reaches out for a headset hanging on the Dialysishouse. He realises that she is busy, and probably will talk for a while with Martin since he overheard her discussing methods to lower Martin's blood pressure with the doctor earlier today. Tom decides that her conversation with Martin is more important than his questions right now. He heads for the office instead. On the way he passes Betty as she greets Martin. Tom whispers: "Don't forget to congratulate him to his MSc!"

Figure 16. *The interaction becomes visible through manipulating the sculptures.*

The scenario shows how the Dialysishouse contribute to the accountability of action as part of the context. Since Tom is able to recognise the sculpture and Betty's action, he can use his knowledge of previous events to interpret the reason, predict the subsequent course of action, and thus make a decision on how to coordinate his own work. It might not be of obvious importance for the supervision of the remote patient that nurses' actions are accountable between

them. However, it is more important for coordination of work at the department, considering that supervision is only a small part of the work that the nurses are doing.

Designing For Accountability and Awareness

To achieve accountability and awareness at-a-glance, we set certain requirements on the system. Awareness required the system to take up space and explicitly show at the distance within a room which patients are having remote dialysis in a non-intrusive way. Accountability of action between nurses required the interaction with the system to be visible to others within a room. These requirements were met by tangible computing.

When designing tangible computing there are a few factors that we can model with. To achieve our goal we decided to work with shape, colours, spatial placement and light. Both Mushroom and Dialysishouse were designed to take up space in order to support awareness. Their physical constitutions differ and affect the possibilities of visibility at a distance. The Dialysishouse does not support the awareness at-a-glance as well as the Mushroom. The advantage with the Mushroom was that it could be placed on a table and viewed from a distance. In the Dialysishouse, the sculptures are placed in the rooms and thus not as visible as the Mushrooms. This is partially compensated by windows that allow viewing into the rooms from the side.

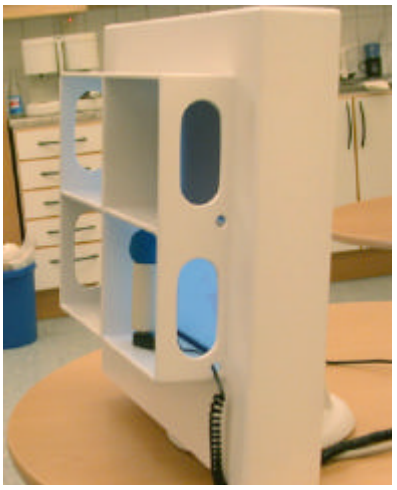

Figure 17. *The Dialysishouse is not as visible from the side as the Mushroom.*

It was more difficult to visualise information on the Mushroom because of its constitution. Means of visualisation were thoroughly discussed. Diodes, colours and movement were alternatives for showing information. However, we found these too limited for the variety of parameters that we wanted to mediate. It proved difficult to design a system completely tangible in a reasonable way. The conclusion was that the kind of visualisation that we were looking for was suitable for a display since it provides easy and flexible ways of representing data. Therefore the Dialysishouse, which offered the possibilities to visualise data on the walls, was chosen. We found that there does not necessarily have to be a contradiction between the idea of tangible computing and the use of displays. The display has physical properties, in our case illumination, which can be used in a tangible interaction model. Still, we wanted to further explore how to develop the Dialysishouse metaphor towards a more tangible solution.

We arranged a workshop with industrial and interaction designers at Umeå Institute of Design in order to discuss tangible solutions. During the workshop alternative solutions were discussed. Also the need for tangible interfaces in this situation was questioned. Finally a

decision was made to further develop the Mushroom, enhancing it with diodes and a touch pad. The results were drawings and a rough mock-up in Styrofoam.

The workshop resulted in our questioning of the use of us carrying out a completely tangible design. It is important to realise which aspects make sense to make tangible in specific projects. It would be possible to support awareness of remote patients by hanging a screen on the wall, which would display patients and information about their treatments. Like the Dialysishouse, a screen is not visible from all angles. Still it would probably be good enough for providing an overview of treatments at-a-glance. Even though awareness of patients probably would be well supported without the physical properties of the Dialysishouse, we argue that the physicality has a certain influence on the accountability of actions.

We see the Dialysishouse design as an example of how it is possible to work with accountability of action. Through its physical properties the interaction becomes explicit and therefore more observable than interaction with a desktop PC. It becomes more observable for at least two reasons according to us. A computer screen suffers from a low resolution with current technologies. The low resolution of screens force the user to concentrate on the representations presented on the screen. A physical object has a higher resolution and is easier to view. With the increased resolution of physical objects the possibilities for awareness are enhanced, as it is easier to glance at physical objects and see their current status. A physical object is also more observable due to its construction, as explained in the TUI model. In a physical construction the input/output are entwined and not separated as in the GUI model. When both input and output are made through a physical interface it is also easier as an observer to see what action related to what result. There is no immediate decoupling between an action and its result, such as with a mouse and result on screen in a GUI.

Several studies have shown that many mechanical systems had the benefits of making interaction observable and interpretable. When these systems have been replaced with computers, the vision of a computer has been the PC with mouse and keyboard as means of interaction. The interaction's visibility was thus reduced to the movements of a mouse and the typing on a keyboard, which conveyed little of what was going on to the colleagues. One way to compensate for the lack of awareness of each other's work would be to provide information on the computer screens like in the Tukan project. The alternative is to use the continuously shrinking size of computational devices and embed them in physical objects, making the users show their actions, like the Dialysishouse.

Conclusion

Accountability and awareness are important concepts in the discourse about cooperative work. They are also concepts that have been of interest to designers of technical artefacts. We have found that accountability in design so far has been more discussed in terms of how a system should account for itself. It has been our interest to investigate another aspect of accountability in design, namely the design's possibility to facilitate accountability of action within a setting. Many studies within the research area CSCW have shown the benefits of the physical design of artefacts. The physical design in the examples makes the interaction visible, which supports accountability and awareness.

This is especially interesting in an environment like the dialysis department, where the work is far from sedentary. Unlike modern office work, most of the nurses' work is carried out in the real world instead of a virtual working space. The nurses' tasks in a higher degree require interaction with people and physical artefacts distributed over the department. This makes the actions observable, a pre-requisite for coordination of work between nurses. An awareness support like the Tukan software is thus insufficient, since it is hidden behind a PC. Instead, the setting requires a system with a visible interaction style, like the rest of the work at the department. We have seen that the aspects of tangible computing create prerequisites for accountability and awareness in a different way than the desktop PC.

When looking closer at the tangible applications that have been developed so far, we find mind shifters that have been useful for thinking about interface design. Dangling string shows us a way of thinking about how to provide awareness in a setting through motion and taking up space. Furthermore, we find hints about designing for accountability in the Geospace project, where the visibility of manipulation of physical objects makes the actions observable and reportable.

The Dialysishouse is our example of how tangible computing can support awareness and accountability of action at-a-glance, through making action visible by requiring interaction with physical objects. It takes up space in the setting, which facilitates keeping an eye on it. The interaction model, consisting of a physical index, requires moving the sculptures, which makes the interaction with the system observable on the distance within a room. The visibility of the interaction makes it possible for nurses to interpret what is going on with the remote patients, and may by this means plan their course of action accordingly.

It is our argument that this visible interaction is valuable for coordination of work in settings like the dialysis department, where actors in a high degree are moving around interacting with physical artefacts. We find this to be an important function for tangible computing that we believe should be further explored in design for CSCW.

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