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This paper presents the preliminary results of our ongoing study on the situated use of home hemodialysis technology by lay patients and carers. The aim of the study is to understand the context in which users interact with the technology, and the strategies they adopt during interactions. In a first phase of the study, we used a Distributed Cognition approach to gather data during visits to patients’ homes. The findings showed that the broader context influenced interactions with the technology. To consider the broader context, we re-conceptualized our analysis in terms of systems, and to allow a structured analysis of these influences, we are developing a Contextual Factors framework in a second phase of the study.

INTRODUCTION

This section provides an introduction to the objectives of our study, to home hemodialysis, and to the Distributed Cognition for Teamwork (DiCoT) methodology.

Situated Used in Home Healthcare

With the anticipated rise in home healthcare, there is a need to ensure that future home medical devices are designed such that they can be safely and easily used by lay patients and carers. To inform the design of these devices, it is important to understand how lay patients and carers currently interact with medical devices in the home environment, in terms of the context in which the devices are used, the difficulties that users face while interacting with the devices, and the strategies that users adopt when interacting with them. In our study, we consider the home hemodialysis machine as an example of a home medical device, and focus on understanding the socio-technical system in which the technology is used.

Home Hemodialysis

Hemodialysis is a treatment for patients suffering from kidney failure. A special filter, called a dialyzer, which is connected to a machine, cleans the patient’s blood. During treatment, the patient’s blood travels through tubes into the dialyzer. The dialyzer filters out wastes and extra fluids. Then the newly cleaned blood flows through another set of tubes back into the patient’s body. The treatment can be done either by a nurse in a satellite dialysis unit, or by a patient or carer in a satellite unit, or by a patient or carer in the home.

In the home hemodialysis setting that we are currently studying, when a patient or carer who is eligible for doing the treatment by themselves at home decides to do the treatment at home, the patient or carer is trained in the satellite dialysis unit by the nurses. When they are ready to do the treatment independently at home, the machine is installed in their home by the technicians, and they commence treatment at home, with ongoing support from a home nurse for treatment-related issues and from technicians for technology-related issues. This forms a distributed cognitive system. To study the physical and social environments in which home hemodialysis technology is used, and how the technology is used in practice, we initially used the DiCoT methodology to structure the data gathering and analysis.

Distributed Cognition for Teamwork (DiCoT)

DiCoT (Blandford & Furniss, 2006) focuses on building models to capture the information flows, physical layouts and artefacts of systems. The Information Flow Model describes the information flows among the actors of the system in terms of the communication channels used and key flow properties. The Physical Layout Model analyses how physical structures at different levels support communication among actors, access to artefacts, and cognitive work. The Artefact Model analyses how the detailed design, structure and use of artefacts aid actors in their cognitive work. Webb (2008) extended DiCoT with two additional models: the Social Structures Model examines how cognition is socially distributed within the system by looking at the mapping between social structures and goal structures, the sharing of work, and how robustness is achieved; the System Evolution Model looks at the evolution of the system over time to understand why work is arranged in a particular way.

DiCoT has previously been applied in the healthcare domain to study how infusion pumps are used in an ICU (Rajkomar & Blandford, 2012) and to study mobile healthcare (McKnight & Doherty, 2008). In this study, we are applying DiCoT to study how home hemodialysis technology is used.

FIRST PHASE OF STUDY

This section presents the methods and main results of the first phase of our study. It shows how we re-conceptualized our view of the context in terms of different systems, and introduces a proposed framework based on contextual factors influencing interaction strategies.

Methods

Data gathering. In this phase, we visited 5 participants, of whom 3 were home hemodialysis patients who did the treatment themselves, and 2 were carers who did the treatment
for a family member. We observed the participants while they prepared for and started the treatment on the machine, and observed or took pictures of the physical layouts where the machine was used. We then conducted a semi-structured interview with the participant. The first part of the questions in the interview guide sought to understand their general experiences of using the technology in the home, while the second part of the questions were based on the principles associated with the DiCoT models and sought to understand the distributed representations that participants used in their activities.

*DiCoT analysis.* We first analysed the data under the lens of DiCoT, guided by the principles associated with the DiCoT models. We saw that, while DiCoT provided leverage for analyzing interaction strategies based on distributed representations, it did not facilitate the analysis of more general interaction strategies that were not necessarily based on distributed representations.

*Open qualitative analysis.* We then conducted an open qualitative analysis of the more general interaction strategies mentioned above, and found that analyzing these strategies, besides the ones related to distributed representations, could also lead to interesting implications for design.

**Results**

*Interaction strategies spanning across immediate and broader context of use.* We found that some interaction strategies involved both the local, immediate, context in which the home hemodialysis technology is used and the broader context. For example, one carer, who does the dialysis for his elderly dad, has to drive to his dad’s place in the morning. To save time, he gets his mum, who is elderly and not trained to care for the patient or use the machine, to start the disinfection phase of the machine while he is on his way. This phase takes about 50 minutes to complete. To enable his mum to do the disinfection, he stuck 4 red dots on the touchscreen of the machine, next to the buttons that need to be pressed to do the disinfection. In this case, the mum is not a part of the home healthcare system (which consists of the patient, the carer, the home hemodialysis machine, the home nurse, the technician, and the medical consultant), but part of the broader home system in which the home healthcare system is embedded.

*Re-conceptualising analysis in terms of different systems, to represent different scopes of context.* The context in which the home hemodialysis technology is used can be conceptualized in terms of different systems that exist independently but all influence the use of the technology, as shown in Figure 1. “Local” refers to the immediate physical context in which the technology is used. “Home Healthcare System” consists of the patient, the carer (if applicable), the home nurse, the medical consultant, the technician, and the home hemodialysis machine and other medical equipment used in the treatment. This system exists solely for the purpose of providing treatment and care to the patient. “Home System” consists of the rest of the home, and includes other family members and home activities. “Dialysis Unit” refers to the satellite unit from which the patient or carer get additional support, for example in case of a emergency, or where the patient gets treated if treatment at home is not possible for some reason. “Society” consists of other home hemodialysis patients that a patient is in touch with, and other hospitals and dialysis units. Note that the objective of this conceptualization is simply to allow a more structured analysis – in practice there is not really a demarcation between the home healthcare system and the home system.

![Figure 1: Conceptualising the context in terms of different systems](image)

The interaction strategy discussed in the previous section involves the local context, in the sense that the carer modified it by adding the stickers to the touchscreen of the machine, and the home system, since the carer’s mum belongs to it.

*Analysing strategies from a DiCoT perspective.* If we analyse the aforementioned strategy from a DiCoT perspective, the insights are: firstly, that the carer shares the goal of doing the disinfection with his mum (an example of social distribution of cognition, derived from the Social Structures Model of DiCoT); and secondly, that the mum, who has no training in using the technology, relies on artefacts created by the carer, i.e the stickers on the screen, to be able to do the disinfection (an example of artefactual distribution of cognition, derived from the Artefact Model). While these are interesting insights, a DiCoT analysis has three limitations. Firstly, it provides enough structure for analyzing parts of the strategy, but in a disjoint manner, that is, it does not facilitate the analysis of the strategy as a coherent whole. This is because it cannot directly take into account the softer and motivational aspects of the strategy. Secondly, it can help to analyse strategies that are based on distributed representations, like the example discussed above, but cannot help to analyse more general interaction strategies, an example of which follows in the next section. Thirdly, DiCoT does not offer a structured way of deriving implications for design.

*Analysing strategies not based on distributed representations.* One patient has her dialysis machine located in her verandah. In winter, when the temperature drops below a certain point, the machine “struggles to maintain itself and starts alarming and things like that”, so she turns on a heater in the verandah to keep the machine heated at the right temperature. This strategy does not involve distributed representations, and hence cannot be analysed with DiCoT, but analyzing it can yield interesting insights on the design.
and use of the technology (for example, it shows how the patient is willing to have the machine in a physical location that is relaxing, at the expense of having to do more to maintain it).

**Coping and optimizing strategies.** The two examples of interaction strategies given above (caring getting mum to do disinfection and patient dialyzing in verandah) both involve optimizing and coping strategies. An optimizing strategy is one in which an actor in the system is already able to execute a function in the system, but adopts a certain strategy to optimize on some benefit. A coping strategy is one in which an actor normally has trouble executing a function, and adopts a certain strategy that enables the execution. In the first example, the optimizing strategy is getting the mum to do the disinfection, the motivation being to save time. The coping strategy is the mum relying on the stickers to press the buttons required for the disinfection. In the second example, the optimizing strategy is doing the dialysis in the verandah, the motivation being that it is a more relaxing environment (optimizing on comfort). The coping strategy is using a heater to keep the machine heated in winter.

**Contextual factors affording/causing optimizing/coping strategies and mediating cross-system strategies.** We can view the context itself as shaping the above strategies. The optimizing strategies discussed above are afforded by contextual factors, while the coping strategies are caused by contextual factors. In the first example, the optimizing strategy of getting someone else to do the disinfection is possible because of the (social) contextual factor that another family member is available in the household to do the disinfection. The coping strategy of relying on the stickers for doing the disinfection is caused by the contextual factor that the mum is elderly, illiterate and not trained to use the machine. There is also a motivational contextual factor which is the raison d'être of the whole strategy, namely that the carer wants to save time. Considering the contextual factors beneath observed strategies in this way has three benefits: firstly, by explicitly considering the motivational contextual factors in the analysis, a strategy that spans across different systems of the context can be analysed as a coherent whole, solving the first limitation of the DiCoT analysis mentioned before – the different parts of the strategy are chained together via the contextual factors, especially, the motivational ones; secondly, since contextual factors are not limited to distributed representations, but can pertain to softer aspects of interactions with technology as well, a more general interaction strategy that is not based on distributed representations can be effectively analysed, solving the second limitation of the DiCoT analysis mentioned before; thirdly, by unpacking the contextual factors associated with a particular strategy, a rich picture of the context and of use in that context can be obtained, highlighting problems that users face and potential interventions regarding technology design.

**Moving from observed strategies to contextual factors to intervention reflections.** After the contextual factors associated with a particular strategy have been unpacked, reflections can be made on interventions that could potentially improve the system, especially if that strategy has been observed across many participants. Intervention reflections can be of many types, for example we may identify a new requirement for technology design, or we may find that a certain element of the design is very important in supporting current practice and should be retained in future designs, or we may identify a need for improving the training. By making these intervention reflections, based on observed strategies and their associated contextual factors, we have a structured way of moving from analysis to design, solving the third limitation of the DiCoT analysis mentioned before.

**SECOND PHASE OF STUDY**

In the second phase of the study, we are currently conducting two analyses in parallel: a DiCoT analysis, focusing on interaction strategies that are based on distributed representations of information, and a Contextual Factors analysis, focusing on interaction strategies that are based on more general issues. This section presents our methods and preliminary findings.

**Methods**

**Data gathering.** We visited 8 participants, of whom 6 were home hemodialysis patients who did the treatment themselves, and 2 were carers who did the treatment for a family member. Our approach was similar to that described in the method of the first phase of the study, except that we probed deeper during the semi-structured interviews to understand the contextual factors and motivations behind participants’ ways of interacting with the technology.

**DiCoT analysis.** We analysed the data under the lens of DiCoT, guided by the principles associated with the DiCoT models. We considered influences from the broader context, using the system scoping depicted in Figure 1 above to help structure the analysis. In this analysis, we focused on interaction strategies that were based on distributed information representations.

**Contextual Factors analysis.** In a separate analysis, we coded the data for optimizing and coping strategies, and then analysed the contextual factors associated with these strategies, and derived intervention reflections (see figure 2 below). In this analysis, we focused on more general interaction strategies that were not based on distributed information representations.

**Figure 2: Steps in Contextual Factors analysis**

**Preliminary Results of DiCoT analysis**

Below are some examples of findings from the DiCoT analysis that show the influence of the broader context on the use of home hemodialysis technology.

**Physical Layout Model: Influence of the home system.**

DiCoT’s Physical Layout Model looks at how space is used to support cognition. One particular patient sometimes forgets to
inject an anti-coagulant into the extracorporeal circuit, to prevent blood from clotting. To avoid this, he employs a strategy of laying out everything that he needs to use on the table before starting, and then removing them one by one from the table, so that in the end, if he has done everything required, there should be nothing left on the table. This is an example of using the physical space to support cognition. However, on one occasion, there were some other random objects, typical of the home environment, on the table – these occluded the anti-coagulant from the patient’s sight, and the patient did not inject it, resulting in the blood clotting in the circuit. This shows how the nature of the home environment can affect the interaction strategies that users employ.

Social Structures Model: Influence of nurses in the dialysis unit. One of the elements that DiCoT’s Social Structures Model looks at is how knowledge is developed and retained in the system. Many participants reported that the different nurses they observed in the dialysis unit took different steps while interacting with hemodialysis machines. While most participants decided to strictly stick to the steps learnt from a particular nurse, as a safety precaution, some participants incorporate what they observed from other nurses in their own interactions with the machine. This shows that, besides the learning that happens through the home nurse (who is part of the home healthcare system), the interaction strategies of patients and carers are also influenced by other nurses in the broader system.

Artefact Model: troubleshooting documentation used by technicians. DiCoT’s Artefact Model looks at how the design and use of artefacts support activity. When patients/carers encounter technical difficulties with the technology, they call a technician (considered part of the home healthcare system in this analysis, though physically located in a hospital or dialysis unit) who assists them over the phone. Typically the patient/carer tells the technician the error code or message displayed on the screen, and the technician looks up the code or message in a troubleshooting document to advise the patient/carer on the steps to take. This troubleshooting document is an example of a mediating artefact. In one particular situation, the technician was unable to find any information in the documentation at his disposal on how to solve a problem with the machine. He told the carer he would have to get in touch with the manufacturer of the machine to get support (which meant the problem remained unsolved for several days, affecting the dialysis routine of the patient). In this example, the limited information immediately available in the home healthcare system affects the treatment of the patient, and the technician has to retrieve information from the broader context.

Preliminary Results of Contextual Factors analysis

Below are some examples of findings from the Contextual Factors analysis that show the influence of the broader context on the use of home hemodialysis technology, in terms of general interaction strategies. In each example, there is a particular optimizing or coping strategy, based on certain contextual factors. These contextual factors point to potential design implications.

Optimising strategy: carer using walkie-talkie to communicate with patient during dialysis. One particular carer bought a pair of walkie-talkies so that, after starting the dialysis treatment for the patient, he can go upstairs to do some other activities in the home. In case of any problem, the patient would get in touch with him through the walkie-talkie, and the carer would come down to handle the issue. This is an example of the home system (broader context) influencing an actor to adopt a certain strategy.

Contextual Factors: 1) The treatment takes about four hours to complete, so naturally the carer wants to do other things in the home during that time. 2) The patient sometimes gets cramps at some point in the treatment, and his blood pressure drops, which requires the carer to come and dispense saline to the patient. Therefore it is important for the carer to be reachable during the treatment.

Intervention Reflections: One design sensitization is that users of home healthcare technology may try to negotiate their presence in both the home healthcare system and the home system at the same time.

Coping strategy: lay users personally fixing problems with the technology due to difficulty in organising dialysis sessions at the unit. When a machine breaks down, and it’s a problem that the technician cannot help the patient/carer fix over the phone, the technician usually requests the patient to get dialysed in the dialysis unit until the technician can visit the patient to fix the machine. We found that, due to difficulties in organizing contingency dialysis sessions at the unit, some patients/carer decide to try and fix the problem on their own, so that dialysis can be resumed at home. This is an example of an influence of the dialysis unit (broader context) on how patients/carers interact with the technology at home. In one particular incident, to fix a water leak problem with the machine, one particular carer stuck some tape on the leak, and proceeded to dialyse his father.

Contextual Factors: 1) It is hard for a home patient to organize a dialysis session at the dialysis unit at a time that is convenient for them, due to all sessions being usually booked out and difficulties in getting other patients to swap sessions. 2) In the incident mentioned, the elderly patient gets very stressed at the thought of having to dialyse in the unit and all the difficulties involved. This was the primary motivation for the carer to decide to try fixing the machine and proceed to dialyse his father (despite the technician’s warning that it would be safer to not use the machine until it is properly fixed).

Intervention Reflections: One implication for design is that a patient/carer may choose to try and fix issues with the machine that normally the technician is meant to fix, making a tradeoff between safety and the stress and difficulties involved for home patients to dialyse in the unit.

Coping strategy: Checking steps with other home patients/carers instead of with home nurse. In some cases, patients/carer choose to contact other patients/carer, whose telephone numbers they have, to double check something they are unsure of regarding the use of the machine, rather than contacting the home nurse. This is an example of society (broader context) influencing how patients/carers interact with the technology.
Contextual Factors: 1) In one particular case, the main motivation for the above strategy was that the patient did not want the home nurse to think that he was not paying attention when she was instructing her on how to use the machine. 2) The treatment is complex, involving many steps, and it is easy to forget how to perform a particular step (especially one that is only performed once in a while and not every time).

Intervention Reflections: One design sensitization is that a patient/carer will not necessarily learn how to use the technology from the home nurse only, but may also be influenced by how other patients/carers use it.

CONCLUSION

The findings of our study so far show that, besides the local, immediate, context in which home hemodialysis technology is used by patients and carers, the broader context also influences interactions with the technology. This applies both in the sense of information representations that are distributed across the context, and in the sense of more general aspects of the context. Understanding these influences from the broader context can lead to interesting implications for the design of home healthcare technology.

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