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User customisation of medical devices: the reality and the possibilities

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Abstract While studies of office environments have treated the customisation of technology by users as a positive response to the situated nature of work, customisation of devices in the medical domain, and other safety-critical domains, when acknowledged, has been treated understandably as a violation and a threat to safety. This paper looks at the customisation of medical devices by nursing staff, based on an observational study carried out in three Scottish intensive care units. Drawing on the insights of ethnomethodology, this paper proposes an alternative approach to the study of user customisation and its organisation. An attempt has been made to go beyond the simple categorisation of types of customisation to explicate the detail of how customisation is carried out. Drawing on concerns in human-computer interaction and arguments in medicine surrounding the use of protocols, the potential for supporting customisation in the medical domain is discussed.

Keywords Medical technologies · Adaptive systems · Customisation · Protocols · Ethnography

1 Introduction

Arguments against systems that fail to adequately reflect working practices and are too restrictive are a perennial research concern in the fields of human-computer interaction (HCI) and computer-supported cooperative work (CSCW). It follows from the growing collection of workplace studies that emphasise the situated nature of computer use, such as the study by Suchman (1987), and tales of user customisation of technologies. These studies highlight the complex relationship between the general pattern of use and the details of particular activities. While the traditional view of interface work is strongly process-based, the function being to guide the user through a regularised sequence of actions, these studies focus on work as the improvised management of contingencies.

However, there has been little attention paid to these topics with regard to the use of medical technologies. This paper looks at the customisation of medical devices by nursing staff in several intensive care units. This is an interesting issue because customisation of devices in this domain, and in other safety-critical domains, when acknowledged, has been treated understandably as a violation and a threat to safety. The customisation of medical devices brings up difficult issues concerning safety and accountability. An understanding of how customisations are carried out is important if we are to deal with the issue, rather than ignore it.

In this paper, I review the literature on the customisation of technologies from the fields of human-computer interaction and computer-supported cooperative work, as well as studies from the medical domain. I next describe the methodology used in this study, and the motivation behind it, and then provide examples of customisations from my study. A later section turns to issues of design and considers the possibility of adaptive systems in the medical domain. I then return to my data to describe the use of adjustable of alarm limits by nursing staff, considering such devices as a type of adaptable system.

2 Previous studies of customisation

Customisation, adaptation and tailoring are all terms that are frequently used, sometimes interchangeably, to describe changes to technological systems carried out by users. These are terms of which we all have an intuitive sense. However, what is meant by these terms is rarely

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clearly defined. Gasser (1986) describes three types of adaptation: *fitting*, where the structure of work is changed in order to accommodate the system misfit; *augmenting*, where additional work is undertaken to make up for the misfit, such as providing extra training or verifying and revising data; and *working around*, where the system is used intentionally in ways for which it was not designed, or where its use is avoided and an alternative means of accomplishing work is relied on. Cook and Woods (1996) distinguish between *system tailoring*, where the users adapt the system to fit with their current cognitive strategies, and *task tailoring*, where users adapt their tasks to accommodate the constraints imposed by the technology.

I will use the term customisation because it most accurately represents the intention of the user—to alter the system to the specifications of the individual or group. I will use the term to refer to activities that directly involve the system (the system including not only the device but also its associated artefacts, such as user manuals), either changes to how the system works or changes to how the system is used. In this, my definition is much narrower in focus than those studies of adaptation and tailoring, which look at not only how the system and its use are customised, but also how users tailor or adapt their own working practices in response to the system. Such studies emphasise the mutual adaptation of technology and organisation (Bikson and Eveland 1996). Rogers (1994) uses the term 'co-evolution' and Mackay (1990) speaks of 'co-adaptation'. While I accept such reciprocity and believe that understanding such a process is clearly important, the motivation behind the decision to focus on customisation is to allow a more detailed exploration of this topic.

Various studies of customisation by users can be found in the fields of HCI and CSCW (e.g., Gasser 1986; Mackay 1990; Gantt and Nardi 1992; Clement 1993; Rogers 1994; Bikson and Eveland 1996), describing various types of customisations, drawn from observations and interviews. I will not attempt to describe the results of these studies here. However, what these studies have drawn attention to is the fact that customisation is often a collaborative activity. Previous studies have also argued for the need for this informal design, which is often unrecognised, to be acknowledged. Customisation is seen as being part of an ongoing and natural process that cannot be completely anticipated.

There have also been studies of adaptation in the medical domain, although they are few and far between. I will describe the two most significant studies here. Obradovich and Woods (1996) provide a study of how nurses adapted a computer-based device for the infusion of terbutaline in the treatment of pre-term labour, for use by women experiencing high-risk pregnancies. The study used three methods for the collection of data. Nurses were interviewed about how they used the device and about how patient-operators used the device. Bench tests were conducted by the authors, to explore how the device behaved, how the control sequences needed to interact with the device over a range of tasks and how the display represented these different states and activities. Nurses were then observed while programming the device to accomplish different tasks. As the devices were to be operated by the patient, and the nurses recognised that the patient-operators were having difficulties in operating the device and understanding the manufacturer's manual, the nurses developed a patient guide. They also modified the procedures for using the device. For example, they told the patient-operator to change the syringe at the same time every day, rather than waiting for the syringe to run out, as was the intended procedure. This ensured that the patient-operator would not have to replace the syringe after being awakened in the night. The nurses felt that this was important because the changing of the syringe is a complex enough task even when fully awake.

Cook and Woods (1996) provide a study of the introduction of a new microprocessor-based physiological monitoring system for use in cardiac anaesthesia. This study used observational methods, focusing directly on the interaction between the anaesthesiologists and the new system. Twenty-five cases were observed, with detailed records being made of twenty-two of these cases. The observers also attended the training sessions offered before the installation of the new system, and informal interviews were sometimes carried out with the anaesthesiologists. The data was analysed using a process-tracing method, to construct behavioural protocols. The default screen on this device limited the practitioner's ability to detect and appreciate the magnitude of rapid changes in blood pressure and heart rate. Through a complex series of steps, a fixed-scale graphical representation of the three blood pressures of interest to practitioners, available as a window, was brought to the screen during the initialisation of the system in the morning. To do this, users made a substantial effort, the setup procedure requiring between 16 and 30 menu activations along three different menu subtrees. They found that adjusting the order of the variables on the screen was essential to keep the window from covering the display space reserved for other waveforms.

3 The methodology

While the studies described above start to give us an idea of the kinds of customisations that are carried out by users, my interest is to explicate the detail of how customisation is carried out in the intensive care unit—the micro level processes. For this reason, I use data from an observational study. Without using such ethnographic techniques, the level of detail required would not have been possible. To rely on methods such as interviews would not only neglect the complex relationship between what people say and what they do, but would also be limited by the researcher's preconceptions, which determine which questions are asked. I carried out unobtrusive observations in three Scottish intensive care

units, spending eight weeks in one unit, followed by two shorter studies of two weeks each. During this time, I worked the hours of the nurses, 7:45 a.m. to 8 p.m., or 7:45 p.m. to 8 a.m., allowing me to get a feel for how the work varies over the day. I spent the majority of my time either sitting by particular patients, or sitting in a position where I was able to observe the whole of the ward. I also attended training on medical devices with some of the nurses, and attended meetings of both nurses and doctors. Because of the complexity of the setting, it was also necessary to carry out interviews to improve my understanding of particular events. However, this was done in an informal way, for example, during coffee breaks and quiet moments. I made notes during my observations, which were typed up at the end of each day. In all of the hospitals, ethics committee approval was obtained.

Observational methods have been used in similar research to uncover how technology is understood, used and adapted in an organisational setting (Barley 1988; Orr 1996). Such methods are also being increasingly used to gain an understanding of a setting prior to design (Schmidt 2000). The advantage of the flexible nature of such ethnographic methods is that the researcher's assumptions are not imposed onto the data in the same way as with quantitative data collection, increasing the chances of discovering evidence discrepant with those assumptions (Hammersley 1992). The customisation of devices was a topic that arose out of my observations, rather than being something that I was 'looking for'. I have witnessed, over a significant period of time, the setting, as opposed to making claims on the basis of data produced in settings specially set up. This leads to more detailed data and avoids generalisations, moving us from abstract theory. By not focusing on one particular issue in my observations, simply recording details of all that I could, I was able to gain an understanding of how the work of customisation fits in amongst the nurses' general concerns and daily routine. I was able to observe how the various groups of nurses viewed and gave meaning to the situations that arose, and how they chose to pay attention to some things and not others. Because I was present for such a long time, I was able not only to observe their behaviour, but I could also ask nurses about their thoughts and feelings in the course of ongoing events.

In understanding my data, I have drawn on the insights of ethnomethodology. While accepting that customisations cannot be predicted in advance, I treat customisation as organised work (Gasser 1986) and it is this organisation that I seek to define. Ethnomethodology understands occupations as self-organising domains of recognisably competent work practices (Garfinkel 1967). Its concern is with how ordinary activities exhibit accountably competent work practices as viewed by practitioners, and how practitioners make sense of situations. The practices of coding and classifying data through the application of predefined taxonomies and analytic frameworks is rejected (Crabtree, Nichols et al. 1998). Instead, the analyst takes a bottom-up approach to understanding the collected data. Thus, we are able to get access to the missing descriptions of occupational activities and how practitioners manage their tasks.

4 Customisation in the intensive care unit

Before moving on to describe some examples of customisation, I will provide an introduction to the setting for those who are unfamiliar with the intensive care unit. In the units where the observations were carried out, there are between five and eight beds. Each patient will typically be attached to the following items:

- A microprocessor-based physiological monitoring system, which is similar in shape and size to a television, with a continuous display of different wave forms on the screen, representing the patient's heart rate, blood pressure, central venous pressure and pulse oximetry saturation (the percentage of haemoglobin which is saturated with oxygen)
- A ventilator, which assists the patient's breathing
- An enteral nutrition pump, which delivers food to the patient's stomach, via a tube through the nose
- Around two to six syringe drivers, delivering drugs to the patient at a steady rate

There may also be other pieces of equipment that are particular to the patient's needs, such as a device for dialysis. All of these devices are placed around the patient.

I describe a variety of types of device customisations in the following section. They are not a drastic departure from the types of customisation described in Cook and Woods (1996) and Obradovich and Woods (1996); in some cases they are very similar. However, what I hope to start to show is how these customisations take place, in terms of who makes the customisations and how they fit in with the work that nurses do.

4.1 Overcoming limitations

Portable monitors are used for transferring patients between wards. The intensive care unit has had the monitors for 4 months. When a patient was being transferred, the monitor being used switched itself off, despite the fact that the battery was charged and should last for two hours. When the nurse switched the monitor back on, a message appeared, saying "BATT COND". On returning to the unit, the nurse informed the ward manager. The ward manager looked up the error message in the user manual and found that the error message refers to the battery condition and means that the battery needs to be replaced. Whether or not the battery has been recharged, it must be replaced after the fiftieth time it is used. The ward manager says that it would be ideal to record the number of times that it is used so that they know when the fiftieth use

occurs, but this is impractical because of a lack of time and a need to perform more pressing tasks. Since this incident, however, they have found that if the same thing happens while transferring a patient, you can trick the monitor by taking the battery out and putting it back in, to "let it forget".

This is an example of a customisation developed as a short-term solution to the fact that it is difficult to keep an accurate record of how many times the device has been used. Mackay (1990), in her study of the user customisation of software, talks of the "perceived costs and benefits" of customisation that determine whether or not a user will customise a system. However, this was a customisation that was perceived by staff to be a necessity, as it affects the nurses' ability to provide adequate patient care. In all of the intensive care units observed, there was a feeling that they were very much alone in managing the technology. Stories were told of reporting problems to manufacturers or distributors and waiting a long time for a reply, if one ever came at all. So, nursing staff learn to customise the devices, or how they are used, to get them to work *in the way that they want them to work*. It is considered to be part of the job; nurses feel that they "almost have to be technicians". However, it would not be considered acceptable to tamper with equipment unnecessarily.

4.2 Pen and paper adaptations

Some adaptations do not affect how the device is used but are simple adaptations to ease the use of the device. Frequently, post-it notes are attached to devices, detailing how to use them, and user manuals may be rewritten, adapting the language and removing unnecessary details to make them easier to understand. Information attached to equipment is usually for equipment that is not used often, where nurses may forget what they have to do. It is also a way of ensuring that everyone knows about changes to the way a device is to be used. Other adaptations include basic things such as an elastic band to keep part of a device in place.

Mackay (1990) found that most people resisted spending much time customising because they are busy. In all of the intensive care units observed, despite being very busy, a lot of time was given to activities such as the rewriting of user manuals. As stated before, such adaptations are seen as a necessity. In one unit, when a new type of ventilator was being supplied by another part of the hospital, the education coordinator and I visited the people providing the ventilator. The education coordinator was given a demonstration of how to use the device and she wrote down, in a step-by-step style, how to set up and operate the device. She later typed up these instructions, and these were used to teach nurses how to use the ventilator, later being kept by the ventilator for reference. When I commented to the education coordinator on the fact that she had not looked at the manual, she responded, "Manuals are a nightmare."

4.3 Changing procedures

Nine months before, a haemofiltration device was purchased by the intensive care unit. The device is designed to also manage the delivery of heparin, an anticoagulant given to assist the haemofiltration. However, the nurses put the heparin through a separate syringe driver rather than through the device because, if they put it through the device, they cannot change the rate of delivery once delivery is started. The decision to put the heparin through the syringe driver was made by the renal core group, a group of nurses responsible for the purchase of the device and also responsible for the subsequent training on how to use the device. After several months of using the device in this way, a critical incident occurred where there was a case of siphonage, meaning that all the heparin was given in one go, rather than being delivered gradually. There was no adverse effect on the patient. The nurses told the clinical physics technicians, who checked the syringe driver to check that it was okay. They also informed the distributor of the haemofiltration device, who passed on the information to the manufacturer. The manufacturer responded by saying that they should not be putting the heparin through the syringe driver but should be putting it through the device. There is a risk of siphonage with any equipment where there is negative pressure (pressure less than that of the ambient atmosphere). The nurses think that the syringe came out of its carriage. Therefore, they will now give the heparin through an infusion pump because it can stand greater pressure (still not putting it through the device). It requires more heparin, which is why they did not use the infusion pumps before. The infusion pumps are not saturated but it is felt that they "have to balance risks" and this is a better alternative to persisting with the syringe drivers.

One way of viewing the incident described is as a violation of the manufacturer's guidelines by the nursing staff, through a direct change to how the device is used. However, this is not how it was viewed by the nursing staff. Again, it was perceived by nursing staff to be a necessity.

Previous studies highlight the collaborative nature of customisation (e.g., Mackay 1990; Gantt and Nardi 1992). Fundamental changes to the way a device is used, such as in this example, are unlikely to be carried out by an individual nurse without previously being discussed with other nurses. The decision to deliver the heparin in this way was a decision taken by the renal core group, where possible options were discussed. When one nurse was showing another nurse how to set up the haemofiltration device, the second nurse questioned why they were putting the heparin through the syringe driver. The point is that such adaptations are not simply the *ad hoc* violations of a single individual, unquestioned by those around; the adaptations are discussed and count as

noticeable events that are open to the questioning of others. It would be unacceptable for a nurse to make an adaptation such as the one described, without consulting others. Making suggestions for adaptations is also not something that we can expect from less experienced nurses. However, for more experienced nurses, this is an opportunity to demonstrate competence.

More generally, the use of equipment is something that is subject to much discussion. Nurses will ask each other how to do something or why something is done a particular way. Talking about devices presents nurses with an opportunity to demonstrate their competence, as has also been observed in other professions (Orr 1996).

So, despite the very situated nature of the work, we see that adaptation, and use of equipment generally, is carried out within a specific ''community of practice'', where such actions are observable and reportable, and therefore accountable, making them subject to the social conventions that determine acceptable use (Wenger 1998).

5 Implications for design

My intention in this section is not to give a simple list of guidelines, as has become common practice at the end of many papers in the technology domain that recount the details of ethnographic studies. As Schmidt (2000) argues, it is not those studies with the specific design recommendations for specific systems that have had the strongest influence on the design of such systems. Rather, it has been those studies that have attempted to question the preconceptions about the organisation of work and how those preconceptions affect design (Button and Dourish 1996). Following in this pattern, I wish to use the details described above to open up a discussion on what a safe system is and how such customisations can be supported, whilst maintaining the safety of the devices that are being customised.

5.1 Protocols in practice

Clearly, customisation is an important part of the introduction of a device. As Bikson and Eveland (1996) state, ''Without invention, there are no tools. Without reinvention, there are no uses''. Moran (2002) describes the customisations made by users as ''everyday pervasive design'', where the customisation ''responds to immediate problems and fixes them''. However, studying user customisation of systems brings up difficult questions surrounding the safety of such customisations and whether we should be supporting or attempting to control such customisations.

We can compare this discussion with a prominent discussion in medicine about the role of protocols. Protocols are seen as a means to enhance scientific practice, reduce variations in practice and enhance the quality of care. For example, following on from the death of a chemotherapy patient who was given an intrathecal (spinal) injection of Vincristine rather than an intravenous injection at a UK hospital, recommendations were made for an explicit procedure for the administration of chemotherapy (Toft 2001).

However, critics argue that protocols are not suitable for all situations, and that an unnecessary use of protocols can lead to deskilling and threaten the healthcare worker's autonomy. Berg (1997a) describes the way in which many protocols are circumvented, tinkered with and interpreted in many different ways, in the same way that the procedures of use for various devices are circumvented. Protocols reinforce a restrictive image of activities, where there is a tendency to perceive the treatment of patients as a sequence of individual, formally rational decisions (Berg 1997b). One of the reasons protocols are so often disregarded is the clash between the formal image of health care practices embedded in protocols and the realities of ongoing, socially and materially situated work.

The difference between written protocols and protocols as they are implemented in equipment is that written protocols are often high level and nurses can adjust their interpretation of a protocol to fit with the work, whereas equipment forces the nurse to follow specified actions in a specified order.

In the same way that it has been argued that it is not a problem with the idea of protocols, simply that the protocols used are inadequate, one could argue that if technology were ''better'' in the first place, customisation would be unnecessary. For example, with better research, designers of the haemofiltration device would know that nurses would want to change the rate of heparin delivery, and designers of the portable monitor would know that it is impractical to expect a record to be kept of how many times the monitor is used. This would require a greater level of research on the part of manufacturers into the working practices of nurses. But, although that would solve the problems described in the examples, the factors underlying such situated activity are unbounded even outside of the medical domain, deriving not only from the system but also from knowledge of social and organisational situations, from ongoing interactions with others, and more (Dourish, 1995). ''New patients produce new problems'' and nurses are not necessarily able to specify beforehand what it is that they will require.

The illusion of medical work as a sequence of individual, formally rational decisions affects our conception of what a safe system is. One could ask why we insist on a level of restriction in medical technologies that is not applied in the rest of medical practice. Berg (1997a) argues that ''the health care worker will often act differently in 'equal' circumstances—and (s)he will not be attracted to a tool which embodies the illusion of a single answer.'' The need for flexibility in medical information technologies has already been highlighted (Heath and Luff 1996). Like protocols, rigid medical devices deny nurses the flexibility they require when problems become difficult.

5.2 Adaptive systems

If we are to allow a degree of flexibility within medical systems, a possible solution is adaptive systems. The idea of adaptive systems is one that has received attention within the field of HCI. By adaptive systems, we mean those that allow users to adapt them to fit with their own working patterns.

If we accept that customisation happens whether it is supported by designers or not, we can turn our attention to increasing the safety implications of customisations that are made, through the provision of customisation mechanisms. In the same way that nurses can change alarm settings within certain parameters, we can imagine allowing variations to devices within a certain acceptable safety level. We can see that customisations could be replaced by much easier and safer solutions, if nurses were able to change equipment. For example, rather than nurses putting heparin through the syringe driver where there is a risk of siphonage, an adaptive haemofiltration device could allow the user to change that aspect of the system so that the heparin delivery rate can be changed once treatment has begun.

To establish which aspects of a system could be potential, and safe, areas for customisation requires a greater collaboration between designers and potential users of the system.

However, while providing more control, customisation also implies costs to the users of the device as devices get more complex. Various modes of use increase the amount that needs to be learnt about a device in a setting where time for training is already limited and where there are already a large number of devices to understand. To adapt a device takes time, but then this has to be balanced against the time that nurses spend customising devices that do not support such customisation.

However, if we look at Dourish's (1995) concept of self-representations, which are treated as "accounts" of the system's activity, this is a potential way of supporting customisation, while at the same time easing interaction. Clearly, the devices described do allow customisation, even if unintentionally. In observing the use of devices in the intensive care units, confusion was caused when a system's behaviour was not understandable (Brown and Randell 2002). Dourish argues for the provision of "information resources which support and inform the decision-making process". Such information would allow customisations to be carried out with a clearer understanding of the workings of the device.

5.3 The limitations of adaptation

A much trickier problem is the question of how to certify an adaptive system in a safety-critical environment. Opportunities for customisation increase the complexity of devices. However, again we have to balance these concerns against the fact that devices are customised regardless. But perhaps we should be reviewing how we evaluate the safety of a device, whether the system is adaptive or not. The Medical Device Regulations 2002 state that the performance of devices must conform to the essential requirements under the *normal conditions of use*. With adaptive systems, the definition of normal conditions of use becomes much harder. Yet, this is also true of systems that users customise themselves. Clearly, the safety of a device changes over time as its use changes.

This is also something to be considered by hospital risk managers. Risk managers need to be aware of customisations, so that an evaluation of the associated risks can be carried out.

Returning to the aims of previous studies of customisation, it is important to give recognition for the work that goes into these customisations. Obradovich and Woods (1996) emphasise the potential dangers of the customisations made by the nurses in their study. Although it is clearly important to evaluate the potential risks associated, the potential benefits of customisations should also be recognised, such as the advantages of a user manual that is more understandable to the nurses.

6 Adjusting alarms

A major concern with adaptable systems is how to ensure the accountability of those who carry out customisations. In this section, I hope to show how the use of a device is determined not only by the technological components, which define how the system will behave, but also by the social components, which determine the acceptable use and behaviour (Dourish 1993). For this purpose, I present a more detailed look at the use of adjustable alarm settings, which we could consider to be an example of an adaptive system.

Alarms are an interesting area. The appropriation of alarm settings by nurses is a widely practiced and accepted procedure in the intensive care unit. However, it is a behaviour that has been questioned by the medical community, due to a fear that 'too many' alarms has resulted in a situation where nurses silence or ignore alarms, or are unable to recognise where an alarm is coming from (Meredith and Edworthy 1995). Similar behaviour has been described in anaesthesia, nuclear power and manufacturing (Gaba, Maxwell et al. 1987). While studies have been carried out looking at how a nursing staff responds to alarms, such as how a staff manages to identify and localise alarms (Svensson, Tap et al. 2000), what these studies do not tell us is the details of how nurses adjust alarms.

Each piece of equipment described above, in the description of an intensive care unit, has an alarm. The monitors and ventilators will alarm if set limits are exceeded. For each set of data that is being recorded by the monitor, there are at least two alarms: a high alarm (which will alarm if the reading goes beyond a maximum level set) and a low alarm (which will alarm if the

reading goes below a minimum level set). The feed and syringe drivers will alarm when the fluid is about to run out. The alarms on all of these devices are both audible and visible.

The devices that have adjustable alarms are the monitors and the ventilators. When a nurse starts her shift, she will check what the alarm settings are on the monitor, and adjust them so that she feels comfortable with them. For example, if the nurse is anxious about her patient, she may set narrower alarm limits so that she is alerted more quickly to a deterioration in the patient's state. Similarly, if the patient's state changes during the shift, the nurse may again adjust the alarm limits to reflect this. The limits that a nurse sets on the monitor are partly dependent on her confidence and experience. A more confident nurse will set wider alarm limits. In this, we can see the adjusting of alarms as an occasion for demonstrating competence. When telling the fieldworker about changing alarm settings, a nurse said "But I must qualify that by saying that I'm experienced. How significant do I think that is? I'd say it is very significant." It would be considered inappropriate for an inexperienced nurse to set wide alarm limits, yet it is acceptable, even expected, for an experienced nurse to do this. Less experienced nurses and agency staff are less likely to silence alarms and often set narrow alarm limits. This is characteristic of the caution shown more generally by new and agency staff, also demonstrated in behaviours such as staying with the patient while more experienced staff will often move to the nurses' workstation to talk or write their patient notes. New members of staff are "watched over" by more experienced members, who will observe their alarm settings and give advice on things such as appropriate alarm levels.

Alarms on the monitor can be silenced completely or can be suspended for either 45 seconds or three minutes. One of the alarms on the monitor will always go when taking blood from the patient, so usually the alarm will be suspended before carrying out this task. An alarm will be silenced completely if the nurse feels that the particular alarm is not important to her understanding of the patient's state or if that alarm keeps going off but it is not significant for the patient's state. However, the low alarms are rarely silenced because a low alarm can be a signal that the monitor is not attached to the patient.

With the ventilators, it is possible to temporarily suspend the alarm for several minutes. A ventilator will always alarm when clearing the patient's chest, so usually the alarm will be suspended before carrying out this task. Already we start to see that although nurses and consultants both joke that when they obtain a new device, "the first thing you need to know is how to silence the alarm", this hides the detail of how alarms are adjusted.

Changing alarm settings is an example of a customisation that allows nurses to be able to get the job done with as little distress for patients as possible. Nurses are aware that alarms can worry patients and visitors because they do not know what the alarm means or whether or not it is for them (the patient may not even know that there are other patients on the ward). Therefore, nurses adjust alarm limits so that alarms are not going off unnecessarily. If the number of alarms going off is limited, it is also easier to detect where the alarm is coming from, as well as creating a more peaceful working environment. What we see is that nurses consider the context, not only regarding the state of the patient but also concerning their own experience, when deciding how to set alarm limits (Brown and Randell 2002).

As alarm settings on a monitor are a demonstration of confidence, they can also be read by others as a demonstration of competence. Not only are the alarm settings visible on the monitor, but each monitor is also attached to a computer that is placed on the nurses' workstation. The nurses' workstation is typically placed somewhere near the middle of the ward and nurses will often be around this workstation, answering the telephone or writing their patient notes there. On this computer, particular readings for patients are shown and alarm settings can be viewed and adjusted.

However, although alarm settings are visible, it is only when the monitor alarms that the alarm settings become noticed by others. If a patient's monitor keeps alarming, the other nurses will hear this. In this situation, it is acceptable for another nurse to silence or adjust the alarm if the nurse responsible for the patient is not at the bed space. This can be done either by going up to the monitor or by doing it through the computer on the nurses' workstation. By saying to the nurse responsible for the patient "Do you want me to silence your alarm?" the nurse is making it clear that the alarm limits are, in her opinion, too narrow. So the alarming of the monitor acts not only as an alert to the state of the patient, but also as an alert to the nurse's actions.

What we can see in all of this is that there are a series of commonly known-to-experienced-staff bits of information, relating to the adjustment of alarms, which are learnt by members of staff over time.

Clearly, technologies do not impinge on or nullify the social conventions that regulate workplace behaviours. In the same way that nurses demonstrate competent behaviour through their interactions with patients, interactions with equipment are equally visible demonstrations of competence, or not.

7 Conclusions

In this paper, I have described instances of the customisation of medical devices by intensive care nursing staff and have described how such customisations are made accountable. Although there are certainly situations where customisation is not plausible or safe, I hope that through the examples given, and through opening up the discussion by comparing it with the arguments for and against protocols, to have encouraged designers

to consider where customisation is suitable and how to develop medical devices that allow users to appropriate them in effective, productive and, most importantly, safe ways.

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References

Barley SR (1988) The social construction of a machine: ritual, superstition, magical thinking and other pragmatic responses to running a CT scanner. In: Lock M (ed) Biomedicine examined, Kluwer, Dordrecht

Berg M (1997a) Problems and promises of the protocol. Soc Sci Medic 44(8):1081–1088

Berg M (1997b) Rationalizing medical work: decision-support techniques and medical practices. MIT Press, Cambridge, MA

Bikson TK, Eveland JD (1996) Groupware implementation: reinvention in the sociotechnical frame. In: Proceedings of the Computer Supported Cooperative Work (CSCW) Conference '96, Boston, MA, 16–20 November, 1996

Brown B, Randell R (2002) Building a context sensitive telephone: some hopes and pitfalls for context sensitive computing. In: Proceedings of Building Bridges: Interdisciplinary Context-Sensitive Computing Colloqium, Glasgow, UK, 9 September, 2002

Button G, Dourish P (1996) Technomethodology: paradoxes and possibilities. In: Proceedings of the Conference on Computer Human Interaction (CHI) '96, Vancouver, BC, 13–18 April, 1996

Clement A (1993) Looking for the designers: transforming the 'invisible' infrastructure of computerised office work. AI Soc 7:323–344

Cook RI, Woods DD (1996) Adapting to new technology in the operating room. Hum Fact 38(4):593–613

Crabtree A, Nichols DM et al. (1998) The contribution of ethnomethodologically-informed ethnography to the process of designing digital libraries. University of Lancaster Press, Lancaster, UK

Dourish P (1993) Culture and control in a media space. In: Proceedings of the Third European Conference on Computer Supported Cooperative Work (EDSCW) '93, Milano, Italy, 13–17 September, 1993

Dourish P (1995) Accounting for system behaviour: representation, reflection and resourceful action. In: Kyng and Mathiassen (eds) Computers and design in context, MIT Press, Cambridge, MA, pp 145–170

Gaba DM, Maxwell M et al. (1987) Anesthetic mishaps: breaking the chain of accident evolution. Anesthesiology 66(5):670–676

Gantt M, Nardi BA (1992) Gardeners and gurus: patterns of cooperation among CAD users. In: Proceedings of the Conference on Computer Human Interaction (CHI) '92, Monterey, CA, 3–7 May, 1992

Garfinkel H (1967) Studies in ethnomethodology. Polity Press, Cambridge, UK

Gasser L (1986) The integration of computing and routine work. ACM Trans Off Informat Sys 4(3):205–225

Hammersley M (1992) What's wrong with ethnography? Routledge, London

Heath C, Luff P (1996) Documents and professional practice: "bad" organisational reasons for "good" clinical records. In: Proceedings of the Computer Supported Cooperative Work (CSCW) Conference '96, Boston, MA, 16–20 November, 1996

Mackay WE (1990) Users and customizable software: a co-adaptive phenomenon. Dissertation, Massachusetts Institute of Technology

Meredith C, Edworthy J (1995) Are there too many alarms in the intensive care unit? An overview of the problems. J Adv Nurs 21(1):15–20

Moran T (2002) Everyday adaptive design. In: Designing Interactive Systems (DIS2002), ACM, London.

Obradovich JH, Woods DD (1996) Users as designers: how people cope with poor HCI design in computer-based medical devices. Hum Fact 38(4):574–592

Orr JE (1996) Talking about machines: an ethnography of a modern job. ILR Press, Ithaca, NY

Rogers Y (1994) Exploring obstacles: integrating CSCW in evolving organisations. In: Proceedings of the Workshop on Distributed Systems, Multimedia, and Infrastructure Support in CSCW, Chapel Hill, NC, October, 1994

Schmidt K (2000) The critical role of workplace studies in CSCW. In: Heath C, Hindmarsh J and Luff P (eds) Workplace studies: recovering practice and informing design, Cambridge University Press, Cambridge, UK

Suchman L (1987) Plans and situated actions: the problem of human-machine communication. Cambridge University Press, Cambridge, UK

Svensson MS, Tap H et al. (2000) Localisation, orientation and recognition of alarms: a comparison between three alarm systems in health care. In: Proceedings of NordiCHI2000, Stockholm, Sweden, 23–25 October, 2000

Toft B (2001) External inquiry into the adverse incident that occurred at Queen's Medical Centre, Nottingham, 4th January 2001. Department of Health, London, UK

Wenger E (1998) Communities of practice: learning, meaning, and identity. Cambridge University Press, Cambridge, UK