Risk Assessment in Healthcare Collaborative Settings: A Case Study Using SHELL

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Abstract. This paper describes a case study addressing risk assessment in a hospital unit. The objective was to analyse the impact on collaborative work after the unit changed their installations. The study adopted the SHELL model. A tool aiming to support the inquiring activities was also developed. The outcomes of this research show the model is adequate to analyze the complex issues raised by healthcare collaborative settings. The paper also provides preliminary results from the tool use.

1 Introduction

Risk assessment in healthcare has been maturing over the last years in USA, Britain, Europe and Australia [1]. At its origins, the focus was on developing a framework for controlling litigation, which has been a major worry for clinicians and hospitals. Studies of medical error in healthcare have brought a growing awareness of the scale of the problems directly and indirectly causing harm to patients. Risk assessment is also at the heart of the concept of clinical governance [2], a management approach making those in charge of healthcare organizations accountable for the quality of care delivered.

Until the 1980s, a major goal of risk assessment was to evaluate the technical and human contributions to catastrophic breakdowns in high-hazard enterprises such as aviation, nuclear power generation and chemical production [3]. Accidents such as the ones that occurred at the Three Mile Island and Chernobyl raised much political and social concern. By contrast, medical mishaps tend to affect single individuals and thus received less attention.

But since the mid-1980s research has begun on the technological and human factors affecting the safety of healthcare systems [4]. Much is already known today about human error, work environments, information overload, attention problems, and human-machine interfaces [5]. One outcome of this research is the widespread acceptance of the models of causation of accidents [3, 6]. We should expect an increased preoccupation with risk assessment as more technological advancements are brought into healthcare.

This paper is related with collaboration technology in two ways. The first one concerns the highly technological and collaborative nature of hospitals, since various types of professionals orchestrate their activities in coordinated and concerted ways. The collaborative setting is part of the problem when mishaps occur and thus should be involved in risk assessment. Research on Computer Supported Collaborative Work (CSCW) may contribute to risk assessment with insights on collaboration and technology use. Secondly, groupware technology may also support risk assessment. I.e., technology is not only part of the problem but also may become part of the solutions. In this paper we address these two facets of the problem. We illustrate our approach to risk assessment in a hospital, analyzing technology changes in a very rich collaborative setting: the intermediate care unit for newborns. Our approach is based on the Software – Hardware – Environment – Liveware – Liveware (SHELL) model [7], well known in the human factors field.

We also discuss a tool we have been developing to support risk assessment. The tool implements gesture-based data management functionality over Tablet-PC, adopting the SHELL model to support the interviewers' activities. The paper is organized as follows. In the remaining of this section we give a brief description of the adopted model. The section 2 describes the case study. The section 3 is dedicated to the SHELL tool. The section 4 discusses the obtained results and provides some conclusions.

1.1 SHELL

The SHELL model characterizes the socio-technical context of working environments, disentangling the relationships between humans, called liveware (L), and four other elements of the working environment [7]: Hardware (H), the physical sources; Software (S), including rules, regulations, procedures and practices; Environment (E), the physical, economic and social aspects influencing human performance; and liveware (L), the other humans operating in the working environment. This additional liveware dimension is fundamental to account for the communication, coordination and collaboration aspects of the working environment.

The interfaces between the SHELL elements define major areas of analysis: liveware-liveware (L-L), liveware-hardware (L-H), liveware-environment (L-E) and liveware-software (L-S). These interfaces define the underlying structure for risk assessment. SHELL has been extensively applied in manufacturing, nuclear power production, aviation, ship and railway operations, and maintenance. Many aspects related with human factors have been analyzed using SHELL, including requirements analysis, safety assessment, psychological issues, accident investigation and human operations.

Concerning the healthcare sector, the number of studies adopting SHELL is scarce. [8] studied the anesthetists' workload in operating rooms, with some emphasis on collaboration issues such as delegation and supervision. [9] used SHELL to define an instrument to evaluate work performance in an intensive care unit. [10] discussed the use of SHELL in developing a healthcare report system. None of these projects adopted the CSCW perspective to analyze collaboration issues. Therefore, one of the major goals of our research was to evaluate the applicability and usefulness of SHELL in the CSCW domain.

2 Case Study

The study was conducted on a hospital specialized in neonatal and pediatric services. The specific target was the intermediate care unit for newborns (designated ECU – Especial Care Unit). This unit receives infants unable to live independently, usually in consequence of premature birth complications, who surpassed the most critical phase and do not require intensive care. Many infants residing in the ECU are in incubators, subject to extended electronic monitoring and receiving enriched oxygen mixtures, while others stay in open cribs and are essentially gaining weight. The unit contains 18 incubators and 13 cribs and most of the time operates very close to that limit (29 to 31 newborns).

The ECU is a rather complex organization. Besides the diversity of clinical cases and care services, the ECU involves multiple players with different goals, cultural background and attitudes. Besides the clinical staff, the parents are also present during long periods (usually between two to six hours a day), apart from the nursing assistants and secretariat. The overall maneuver entails the collaboration of all players. The nurses take one of the principal roles there. They have a constant presence in the infants' rooms. They support the detection on abnormal situations, the containment of their consequences and the restoring of the normality. They are also responsible for controlling the nursing assistants and interacting with the parents and doctors.

The doctors are always available in emergency situations to diagnose problems, prescribe treatments and coordinate the nurses' actions. The parents' presence is encouraged, particularly for the infants that already stay in open cribs. They collaborate in feeding their babies, holding them, etc. The nursing assistants are essentially responsible for hygiene and fetching and delivering materials.

The reasons for studying this unit were threefold. First, the unit handles collaboration at a reasonable pace that offers good opportunities for external observation. Secondly, it has a diversity of players and collaboration requirements. Third, the unit recently suffered a complete change of their installations and the hospital administration showed interest in assessing their impact. Furthermore, as the new ECU started operating in January 2008, the players still remember objectively the details of the antecedent situation.

The study was based on interviews and long visits to the premises with several stakeholders: hospital administration, unit's executive board, head of the hospital informatics department, unit's principal nurse and one of the chief doctors.

2.1 Assessment of the environmental changes

The interviews and visits to the ECU were framed by SHELL. The model provided the structure necessary to disentangle many aspects of work in the ECU, elucidating the fundamental drives behind the structural changes caused by the new installations. In this section we will also rely on the SHELL model to summarize our findings.

The liveware elements (L) collaborating in the ECU are doctors, nurses, nursing assistants and parents. Most of the work depends on the clinical staff. We found the nursing assistants are regarded quite distinctively from the other staff; presenting a lower level of education, being subject to different management rules and rotating a lot between units. The parents participate in the process but are mostly regarded as external entities.

The collaboration depends on many regulations and procedures, as well as practices and traditions (S). The most relevant hardware (H) found in the ECU includes incubators, medical equipment, and computers. We observed nurses most frequently handle this hardware, especially computers, which are seldom used by doctors. The nursing assistants emerge again very distinctively as they operate their own and specific equipment.

All liveware share the same physical environment (E), consisting of several rooms, offices and corridors. The complete renovation of the ECU introduced significant changes in this environment. Therefore, (E) should be considered the control variable in this study. The following main changes were identified:

- New automatic electric doors isolating the ECU from the other units.
- The previous infants' rooms had small windows so their interior could be seen from the corridor. Now they have glass walls and are completely visible from within the unit.
- New automatic electric doors isolating the infants' rooms from the corridor. In the previous condition these doors were permanently kept open.
- The unit has an office for the chief nurse and a doctors' room. In the previous conditions these rooms were located far away from the unit.
- New working and cleaning rooms. The incubators previously serviced in the corridor are now serviced in the cleaning room.
- As before, the computers are placed in the main corridor. But they are now in a different position, facing the corridor and with glass walls behind.

We now discuss these changes according to the areas of analysis proposed by SHELL:

L-E. The automatic doors contributed to reduce the ambient noise to more comfortable levels, with positive impact on the liveware and their activities. It was considered that the doors increased the parents' awareness and care for the work performed in the unit, which lead to a quieter attitude. Furthermore, the nurses now spend more time working in the infants' rooms rather than moving immediately to more private premises. The interviewees found two major reasons for this new attitude: the increased quietness stimulates the nurses to accomplish their tasks inside the infants' rooms; and the increased noise isolation refrains nurses from leaving the infants' rooms unattended.

The glass walls had a significant impact on the nurses, as they now have a clear view of the incubators and organize more swiftly their interventions. The nurse office and the doctors' room contributed to the longer presence of the principal nurse and the doctors in the unit. The working room was also welcomed, as the previous situation was characterized by the unpleasant coexistence of very different functions, such as cleaning, eating and writing.

L-H. The new position of the computers in the main corridor affords working on the computer and at the same time controlling the incubators through the glass walls. The location of these computers in the previous environment disallowed such level of awareness.

As in the previous setting, the ECU has an emergency incubator located in the end of the main corridor. However, since the corridor is much longer now, the doctors are considering the necessity to obtain a new emergency incubator to be located in the other end of the corridor, since more time is taken to respond to emergency situations.

L-L. According to the interviewees, the new ECU supports more structures work, more quietness, better awareness, and more fluidity and collaboration. The nurses reported lesser coordination problems and the same level of communication necessary to handle emergency situations. The doctors and the principal nurse spend more time in the unit, which was very positively regarded. There is less conflict between the nursing assistants and the other staff, because maintenance tasks have been relocated from the main corridor to a specialized room. One negative outcome of this new arrangement is that by the end of the day, when the staff is reduced, the nursing assistants leave the incubators' rooms unattended.

L-S. The new environment changed the relationships between staff and rules and procedures, although more time is necessary to detect more profound changes (the new ECU was operating for three months when the interviews were done). One change is related with the nursing assistants. Since the rotation of these resources is very high and there are strict rules about hygiene, disinfection, etc., there is a constant need to instruct the new personnel on those matters. While in the past the instruction was done at the corridors, it has now moved to the service room, with positive impact on the remaining activities.

The outcomes from this study showed the new working environment had a very positive impact on the unit's responsiveness and safety. The SHELL model facilitated establishing the causal relationships explaining the positive outcomes (Figure 1). From our point of view, the model served very well the set research goals.

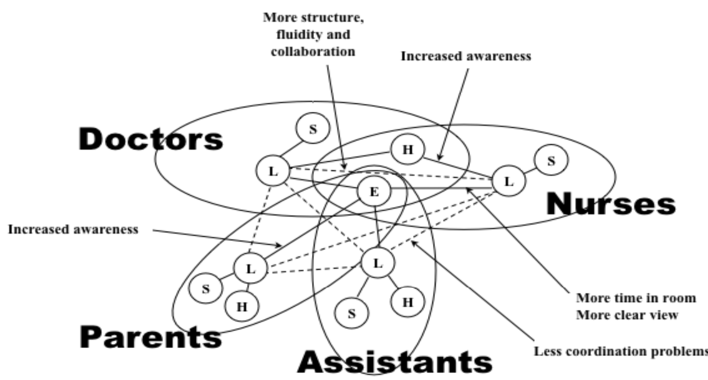

Fig. 1. Schematic view of the ECU unit according to the SHELL model.

3 SHELL Tool

The SHELL tool aimed to facilitate the elicitation of the SHELL model elements, using the touch-screen features and mobility of Tablet-PC. The analysts used the tool to record findings during interviews and observations in the hospital. The tool offers additional features to those of the pen and paper: the annotations may be organized immediately and there are pen-based editing options making the manipulation of the information more comfortable. For this, the SHELL tool captures the strokes handwritten over the Tablet-PC screen, along with the recognition of predefined gestures for triggering edition functions. The tool enables analysts maintaining visual contact with the collaborative setting.

The user-interface consists of a main working screen, where the analyst may take notes about the subjects (liveware). These notes are recorded inside nodes labeled with the name of the subjects. The nodes are represented by rectangles created by gesturing an "|_". This gesture is automatically recognized as a node creation (see Figure 2). The other SHELL model elements are specified inside each node. This is done by clicking with the pen over the node (Figure 2, right side), which makes an arrow pointing down to appear at the top-left corner. By clicking on that arrow, the node is "opened-up" and the whole screen shows four predefined sub-nodes corresponding to the SHELL elements (figure 3, left side). Each sub-node should be filled with the information elicited by the analyst. In this way the "father" node along with the four "son" nodes conform the relationships L-L, L-S, L-E, L-H over which the SHELL model is applied. This enables an easy analysis of the collaborative situation. When working inside a node, an arrow pointing up is always displayed and serves to leave the node (Figure 3, left side).

Fig. 2. creation and selection of a node

The recursive creation of model elements is not allowed. When entering text in a node, if the bottom of the screen is almost reached, then the working area is automatically scrolled up to give the user more space to enter information. To scroll up and down, a panning mode may be activated using an option in the menu. In this mode, gestures up and down will scroll the working area instead of writing a stroke. The editing functions are activated by strokes matching pre-defined gestures having certain meanings, for instance: a) a double lace selects all the strokes inside it; b) a cross deletes all strokes touched by it or previously selected; c) selected objects may be moved by dragging them; f) a spiral gesture copies the previously selected strokes.

Fig. 3. Left side: The working area related with one interviewed person and the SHELL sub-nodes. Right side: Close-up of the menu. Above menu closed; below menu open.

3.1 Observations from the tool usage in the case study

The preliminary interviews and visits to the hospital were conducted with the traditional data elicitation tools, paper and pen, to avoid surprise and discomfort. The SHELL tool was only introduced in the process when it was considered that a good relationship was established between the analysts and the interviewees, the goals of the study were well established, and the purpose of the tool was understood.

The SHELL tool was then used as a substitute for the paper and pen, usually departing with empty pages, filled with hand-scribed text as the interviews progressed. The tool served to organize risk issues (problems, causes and effects) and focus the interview on the SHELL elements. The data elicitation always departed from a specific liveware element – the interviewee –, from where multiple L-L, L-S, L-E and L-H relationships were established. After these experiments, two informal interviews were conducted with the tool users. These users were not involved in any way in the tool development.

The following observations were drawn from the interviews. The interviews and visits usually took a long time and challenged the autonomy of the Tablet-PC. The connection of the power plug was not possible most of the times. The tool usage was thus accompanied with a discouraging level of stress. The hardware was considered more problematic than the software.

The software was considered simple to learn but not simple to master. Most of the problems concern the use of special gestures necessary to organize and edit information. Some of the gestures used to manipulate information were similar to the way one user was accustomed to write, thus resulting in unintended recognized gestures. Most difficulties were related to deleting information since, when it fails, users find an unwelcome drawing, which has to be deleted and so the problem is recursive. The failures had to be recovered in front of the interviewees, which increased the stress. These problems were somewhat mitigated by having two persons doing the interviews, being one more focused on annotating and the other on interacting with the interviewees. But even in these situations using the tool was regarded as problematic, as the user must keep up with the interview.

4 Discussion and Conclusions

The SHELL model allowed us to obtain very insightful data about the consequences of the installation changes done by the target organization. Of course, many of those changes were intended by design. For instance, the glass walls and the new rooms were intended by design to improve the ECU's structure and performance. However, as mentioned by the hospital management, there had not been any previous attempt to assess if those changes had the expected impact on performance. The results showed a remarkable improvement in the overall work structure, with positive impact on performance (less coordination problems) and safety issues (more awareness and presence from nurses and doctors).

The SHELL model allowed us to focus on the fundamental drives of change when inquiring about the changes, and highlighted the causal relationships between the installation changes and the L-E, L-H, L-L and L-S model elements. Therefore one outcome from this case study is the very positive role of SHELL elucidating the complexity of the collaborative work done in the hospital unit, and the causal relationships explaining what occurred after the installation changes. The SHELL model also demonstrated flexibility and plasticity to the varied situations that were encountered during this study.

One curious outcome of this study is that a small number of negative impacts and increased risks were found. Indeed, only two major issues were raised, one related with the increased distance between the emergency incubator and the infants' rooms, and another related with the lesser availability of the nursing assistants by the end of the day.

We observed that, beyond the changes intended by design, some unexpected consequences occurred. For instance, the more presence of nurses in the infants' rooms was not deliberately designed. It just occurred as an indirect consequence of having automatic doors separating the ECU and parents assuming a different attitude. From our point of view the SHELL model was invaluable pointing out these important consequences and the causal relationships explaining them.

The SHELL model was also invaluable disentangling the collaborative nature of the work done in the ECU. The model has a strong focus on the liveware element, which emphasizes the human aspects of the system under evaluation. But the model also emphasizes the L-L relationships, which were instrumental to analyze what was happening with the collaboration in the work setting. Most of the positive outcomes coming from this study were related with L-L relationships (better work structure, more awareness, more presence, less conflicts between staff), indicating a positive role of SHELL assessing the collaborative setting.

This research project thus had very positive results. From the hospital management point of view, the project was their first opportunity to address risk assessment with a focus on collaborative settings. From our point of view, this research was a preliminary step towards applying the CSCW view to risk assessment in the healthcare domain.

Currently, our experiments with the SHELL tool served to highlight the possibilities and problems of such a kind of tool. The obtained preliminary outcomes showed some resistance from the analysts towards using the tool. More work has to be done improving the functionality and, most importantly, increasing the capability to manage the model in a more comprehensive (e.g., integrating data from multiple liveware) and collaborative way (e.g., supporting multiple persons working on the same model, a functionality currently supported by the tool but that has not yet been experimented).

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