Assessing Risk in Healthcare Collaborative Settings

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Abstract

This chapter describes a case study addressing risk assessment in a hospital unit. The objective of the case study was to analyse the impact on collaborative work and work flow after the unit changed its design and installations, and the consequences for risk management. The Software-Hardware-Environment-Liveware-Liveware (SHELL) model, a conceptual framework for understanding the interaction between human factors (liveware), computers (software and hardware) and the environment, was used in this study. The outcomes show that the SHELL model is adequate for analyzing the complex issues raised in healthcare collaborative settings. The SHELL analysis highlighted how the relationships among doctors, nurses and assistants – expressed according to the software, hardware, environment and liveware elements – evolved in the new work setting, characterized by new working rooms, glass walls and automatic doors. This analysis shows that even small changes, such as changing the way that computers are used in the work environment, may have a significant impact in a collaborative work setting.

Keywords: Risk Assessment, healthcare, collaborative Settings, SHELL model, human-computer interactions

Introduction

Risk management in health care has developed and matured over the last many years in the United States, Britain, Europe and Australia (Vincent, 1995, p. 2). At its origins, the focus was primarily on developing a framework for controlling litigation, a major worry for clinicians and hospitals. Studies of medical error in health care have brought a growing awareness of the scale of the problems directly and indirectly causing harm to patients (Reason, 2008, p. 92; Toft, 2001, p. 40; Walshe & Boaden, 2006, pp. 1-6). The direct financial costs of these events, in terms of additional treatment, extra days spent in hospital, and financial compensations, are clearly vastly greater than the costs of performing an initial risk management. The indirect costs associated with lost working days, health losses, disabilities and deaths are greater still.

There is also today a much greater recognition of the human and social costs associated with medical errors. Many patients suffer increased pain, psychological trauma, depression, anger and bitterness (Ennis & Vincent, 2008). Staff may also experience shame and guilt, as well as penalties (Grepperud, 2003). The doctors and nurses whose confidence may have been impaired may also work less effectively and efficiently.

Risk management is also at the heart of the concept of clinical governance (Walshe, 2001), a management approach making those in charge of healthcare organizations accountable for the quality of

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care they deliver. Risk management is therefore evolving and expanding well beyond its roots in litigation and becoming an essential decision-making instrument in health care.

With regard to technology, until the 1980s, one major goal of risk management was to limit the technical and human contributions to catastrophic breakdowns, mostly in high-hazard enterprises, such as air transportation, nuclear power generation, and chemical production (Perrow, 1999; Reason, 1997). Accidents such as the ones that occurred in the Three Mile Island and Chernobyl power plants raised much political and social concern. By contrast, medical mishaps mostly affect single individuals, albeit in a wide range of healthcare institutions, but tend to receive less attention.

Since the mid-1980s several interdisciplinary research groups have begun to investigate the technological and human factors affecting the safety of healthcare systems (Leonard, Graham, & Bonacum, 2004). Much is already known today about the complex relationships between technological failures and human error, highlighting issues related with dynamic environments, multiple sources of concurrent information, mediation effects, time pressure, information overload, attention problems, and problematic human-machine interfaces (Redmill & Rajan, 1997; Sheffi, 2007). One of the most significant consequences of the collaboration between health care and technology specialists is the widespread acceptance of models of causation of accidents (Perrow, 1999; Reason, 1995). For instance, Reason (2008, p. 97) developed the Swiss Cheese Model (SCM) characterizing the trajectory of accidents through “gaps” in a succession of defensive layers, including physical protection, engineered safety features, administrative control, protective equipment, and the frontline personnel themselves. The “gap” concept encompasses active and latent failures, the former associated with operators’ unsafe acts and the latter resulting from erroneous decisions made by designers, developers and managers.

Nevertheless, as more technological advancements are brought into the health care domain, not only associated with high-tech equipment (e.g. imaging), but also with other technologies such as dynamic accounting systems, electronic patient records, workflow management, and the use of mobile devices (Tan, 2005, p. 523), these will contribute to an increased number and variety of risks. We thus expect the concern with risk management to increase in the future.

This chapter addresses the risk assessment of the impact of technology on collaborative activities in hospital settings. The focus on collaboration emerges from two major forces. The first one concerns the collaborative nature of hospital settings; hospitals have long been regarded as inherently collaborative, since various types of highly proficient individuals must orchestrate their activities, in coordinated and concerted ways, and depend on technology all along that process. As a consequence, the collaborative setting is part of the problem when mishaps occur, and thus should be carefully considered when assessing risks. The second force is associated with the increasing adoption of collaborative technology itself (e.g. shared access to patient records) in the hospital environment (Bardram & Bossen, 2005; Rodriguez, Favela, Preciado, & Vizcaino, 2005; Tentori & Favela, 2008), which naturally increases the relationships between risk, technology and collaboration.

Computer Supported Collaborative Work (CSCW) is a research area addressing the study of technology-assisted activities carried out by groups of collaborating individuals (Baecker, 1993). This research area, which gained momentum in the early 1980s (Oravec, 1996, p. 31), is also characterized by bringing together researchers from quite different fields, such as systems engineering, social sciences, management, ethnography, cognitive engineering, media studies, and many others. Considering the amount of accumulated research on CSCW, we believe this area may significantly contribute with theory and models necessary to understand collaborative work settings such as hospitals.

In this chapter we illustrate our CSCW approach to risk assessment in a major public hospital, specifically addressing the analysis of technology changes in a very rich collaborative setting: the intermediate care unit for newborns. The approach is based on the Software – Hardware – Environment – Liveware – Liveware (SHELL) model (Edwards, 1972, 1988; Hawkins, 1987), well known in the human factors field.

First a brief description of the model adopted to analyze risk issues related with technology changes in the hospital environment will be provided. The following section describes the case study, including a brief overview of the hospital where the research was conducted and our outcomes using the SHELL model approach. Finally the results obtained and some conclusions are provided.

Collaborative Settings and Risk Assessment

Four major socio-technical elements influence risk assessment in collaborative settings. These four elements are (Cacciabue, 2004, p. 15): (a) organizational processes; (b) personal and external factors; (c) local working conditions; and (d) defenses, barriers and safeguards.

Organizational processes. It is now well accepted that large-scale organizational decisions have deep consequences on the way in which people act individually and collaborate in groups. Cultural traits are the root cause of most corporate behavior and organizational culture, which pervades all work processes (Hofstede, 2001). Aspects pertaining to organizational culture, like diffusion of responsibility, have been associated with medical errors, such as giving the wrong prescriptions or decreasing intensity of observation (West, 2006). Therefore, organizational culture is an important factor to be considered when assessing the way in which workers communicate, coordinate and collaborate. Organizational and cultural traits are thus important factors, called “resident pathogens” (Reason, 1990, p. 197), playing a relevant role in risk assessment and risk management.

Personal and external factors. Personal traits and external factors are amongst the most important determinants of human behavior (Cacciabue, 2004, p. 16). External factors include all random physical and system contingencies that may change local working and safety conditions, and adequate system performance and human behavior. Personal factors are individual, physical or mental conditions that affect human behavior. They can only be understood in context, although generic classes of human behavior may be identified.

Local working conditions. Local working conditions express the physical and social contexts in which operations take place, including noise, space, light, temperature, physical distance, organizational power, social climate, management style, etc. (Maurino, Reason, Johnston, & Lee, 1995) They are probably the most relevant factors affecting workers’ behavior in collaborative settings, considering in particular the decision-making processes, as the workers are immediately related to the environment.

Defenses, barriers and safeguards. Defenses, barriers and safeguards (DBS) are structures and components, both technological and social, which are designed, programmed and inserted in the system with the purpose of making it safer in normal and emergency conditions (Cacciabue, 2004, p. 17). DBS may be defined as the measures developed by the organization aimed at creating awareness, warning, protection, recovery, containment, and escape from hazards and accidents.

The SHELL model encompasses the whole socio-technical environment that characterizes technological contexts, concerning people, personal and external factors, organizational processes, local working conditions and DBS. The SHELL model disentangles the complex relationships between humans, called liveware (L), and four other elements of the working environment (Edwards, 1972, 1988; Hawkins, 1987):

Software (S). Rules, regulations, laws, procedures, customs, practices and habits governing the way things are done.

Hardware (H). Physical sources, such as equipment, materials, interfaces and machines.

Environment (E). The physical, economic, political and social aspects of the working context, which may indirectly influence human performance.

Liveware (L). The other humans operating in the working context. This additional liveware dimension is necessary to account for the communication, coordination and collaborative aspects of the working context.

An important characteristic of SHELL is that it may be applied for studying, in a very comprehensive way, any types of risks that may occur in working contexts, including organizational, personal and local factors. All possible combinations among the four constituents of SHELL can be accounted for and all their interfaces may be analyzed. It is usual to consider that the human being (L) plays a central role in a system basically made of other humans (L), environment (E), hardware (H) and software (S).

Therefore, the model posits five major areas of analysis: humans (L), liveware-liveware interface (L-L), liveware-hardware interface (L-H), liveware-environment interface (L-E) and liveware-software interface (L-S). These five major areas of analysis therefore constitute the underlying structure for risk assessment.

The SHELL model has been extensively applied by many organizations in different industrial sectors, including manufacturing (Wilson-Donnelly, Priest, Salas, & Burke, 2005), nuclear power production (Wilpert & Itoigawa, 2001), aviation (Garland, Wise, & V., 1999), ship (Itoh, Mitomo, Matsuoka, & Murohara, 2004) and railway (Rizzo & Save, 1999) operations, driving (Barjonet, 2001) and maintenance (Johnson, 2001). Many fundamental aspects related with human factors have been analyzed using SHELL, for instance, requirements analysis (Felici, Sujan, & Wimmer, 2000), safety management (Rizzo & Save, 1999), psychological issues (Barjonet, 2001), accident investigation (Shappell & Wiegmann, 1997) and human operations (Helmreich & Davies, 1996).

In the healthcare sector, the number of studies adopting SHELL is scarcer. Leedal and Smith (2005) did a study on anesthetists' workload in operating rooms, with some emphasis on collaboration issues such as delegation and supervision. Helmreich and Davies (1996) departed from SHELL to define an instrument to evaluate work performance factors in an intensive care unit. Rizzo and McEvoy (2008) discussed the possible use of SHELL in developing a voluntary error report system in the healthcare domain. But none of these research projects adopted the CSCW perspective to analyze collaboration issues. Therefore, one of our major goals was to evaluate the applicability and usefulness of SHELL in the CSCW domain.

Case Study

Setting

The study was conducted in a Portuguese medium-sized hospital with 85 beds and around 800 employees. This unit is a highly specialized public hospital, whose main mission is providing neonatal and pediatric services to the 1.5 million inhabitants of the Lisbon region (in conjunction with several general hospitals). It is a primary choice for the most complex cases.

The selected target was the intermediate care unit for newborns (designated ECU – Especial Care Unit). This unit offers individualized health care for infants that are still unable to live independently, usually as a consequence of premature birth complications, but who have surpassed the most critical phase and thus do not require intensive care. Many infants residing in the ECU are still in incubators, in rather difficult conditions, subject to extended electronic monitoring and receiving enriched oxygen mixtures, while others already stay in open cribs and are essentially gaining weight. So we may generally say that the ECU handles the cases that were ready to leave the Intensive Care Unit (ICU), but are still not ready to leave for home. The unit contains 18 incubators and 13 cribs and most of the time operates very close to that limit (29 to 31 newborns).

From an organizational point of view, the ECU is a rather complex unit. Besides the diversity of clinical situations and care services, the ECU involves multiple players, sometimes with different goals, cultural backgrounds and attitudes. In fact, besides the clinical staff, including doctors and nurses, the nursing assistants and secretariat, the parents are also present during long periods (usually between two to six hours a day).

The workflow entails the collaboration of all players in a rather intricate relationship. The nurses take one of the principal roles there (contrary to the ICU that is much more centered on the doctors). They have a constant presence in the infants' rooms, monitoring the babies' conditions and of course performing multiple healthcare procedures. On the vigilance strand, nurses support both the detection of abnormal situations, the containment of their consequences, and the restoration of normality. They are also responsible for the assignment and verification of tasks to the nursing assistants and for the interaction 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 usually encouraged, particularly for the infants that already stay in open cribs. The parents collaborate in feeding their babies, holding them, etc., and they generally interact with their child both physically and verbally. The nursing assistants are essentially responsible for hygiene issues (e.g., incubators) and fetching and delivering materials and consumables (e.g., the infants' meals) from other units.

The reasons for studying this unit were threefold. First, it still provides critical care services, thus encompassing the inherent risks associated with these scenarios, but at a pace that offers better and less obstructive opportunities for external observation (especially compared with the ICU which is extremely intense and stressful). Second, the diversity of players and collaboration requirements hold a richer study field than other more homogeneous units (e.g., the infirmary). Third, the unit recently underwent a complete change of their installations – they moved to a larger physical space, received new incubators and monitoring equipment, and consequently had to redesign their workflow.

No risk assessment had been performed to understand the impact of changing the workflow. Furthermore, as the new ECU started operating in January 2008, the players still remembered the antecedent situation and had those details very clearly in their mind.

The study was based on interviews and visits to the premises. The authors visited the installations both before and after the changes were made. Several interviews were conducted with the hospital administration and the unit executive board, for comprehension of the management and research goals. The head of the informatics department, responsible for the deployment of hardware and software in the hospital, was also interviewed. Several interviews were conducted with the unit's principal nurse and one of the chief doctors. Some interviews were conducted jointly, with a nurse and a doctor, while others were conducted separately. Besides these interviews, both the principal nurse and the chief doctor guided several visits to the ECU.

The research was cleared and approved by the hospital administration. Special care was taken to avoid increasing the risk associated with the operations under analysis. The unit of analysis was the whole unit, not individual persons. Any detailed information was kept confidential, and the research findings were reported first to the hospital administration.

Assessment of the environmental changes

The interviews and visits to the ECU were prepared and conducted taking into consideration the fundamental elements of the SHELL model. Considering the complexity of the interactions between the different actors intervening in the ECU, the SHELL model provided the structure necessary to disentangle many aspects of complexity, elucidating how work was organized, and identifying the fundamental drivers behind the structural changes introduced by the new installations.

According to SHELL, the following liveware elements (L) collaborate in the ECU: doctors, nurses, nursing assistants and parents. Most of the organizational work depends naturally on the clinical staff, i.e. doctors and nurses. Nursing assistants are regarded quite distinctively by doctors, nurses and parents; 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 multiple organizational 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 that are seldom used by doctors. The nursing assistants emerged again very distinctively as they operate their own cleaning equipment, which is not even regarded as belonging to the hospital.

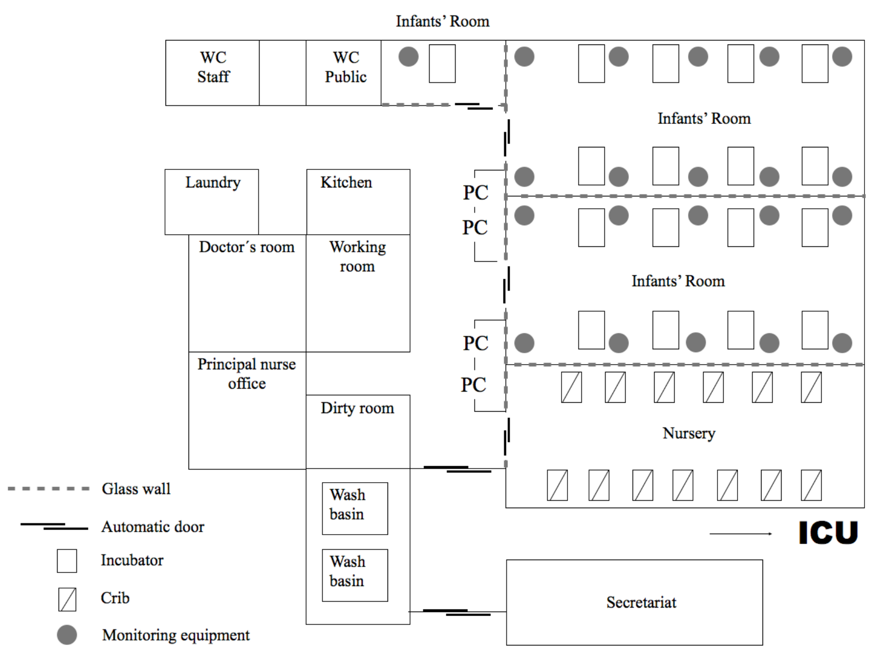

Figure 1. Current physical layout of the ECU. Note the cribs and incubators are movable and may be found in slightly different arrangements.

All of the liveware groups share the same physical environment (E), consisting of the several rooms, offices and corridors shown in Figure 1. 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:

- There are now automatic electric doors providing physical isolation between the ECU and the other units (excluding the ICU, which has a more direct connection to the ECU).
- The previous environment had small windows that allowed viewing the rooms' interior from the corridor. Now the infants' rooms are completely visible from the outside through large glass walls.
- The infants' rooms now have automatic electric doors keeping the rooms isolated from the corridor. Previously these doors were permanently kept open.
- The unit now integrates an office for the chief nurse and a doctors' room. Previously these rooms were located far away from the unit.
- The unit has a new specialized working room used by nurses for various purposes, e.g. preparing food.
- The incubators are now serviced in the cleaning room, instead of the corridor, as in the previous conditions.
- 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 different areas of analysis proposed by SHELL and illustrated diagrammatically in Figure 2.

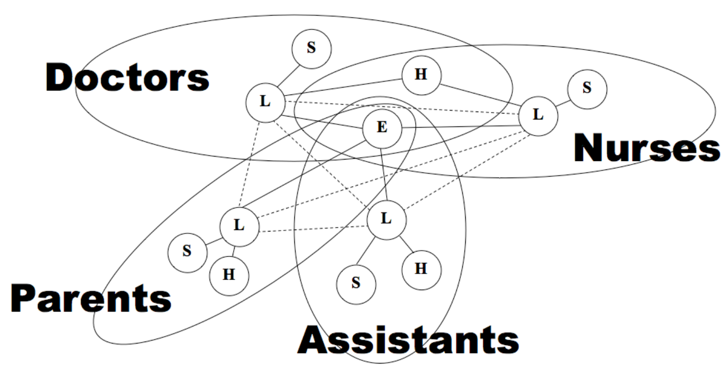

Figure 2. SHELL model of the ECU unit. This summary diagram shows the different types of elements involved in the analysis (S – Software; H – Hardware; E – Environment; L – Liveware).

L-E. The automatic doors contributed to reducing the ambient noise to more comfortable levels, with a positive impact on the different liveware and their activities. It was considered that the doors increased the parents' awareness and care for the work performed in the unit, which led to a quieter attitude (Figure 5).

Furthermore, the nurses now spend more time working in the infants' rooms rather than moving immediately to more private premises (Figure 3). The interviewees found two major reasons for this new attitude: the increased quietness and noise isolation stimulate the nurses to accomplish their tasks inside the rooms, instead of leaving as soon as possible to their offices.

The glass walls had a significant impact on the nurses, as they now have a clear view of the incubators and are able to more swiftly organize their interventions (Figure 3). The principal nurse's office and the doctors' room contribute to the increased 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 positioning of the computers in the main corridor allows division of attention between the computer and the incubators and cribs that are now visible through the glass windows behind the computers (Figure 3). The location of the computers in the previous environment required the nurses to lose sight of the incubators and cribs.

As in the previous setting, the ECU has an emergency incubator located in the end of the main corridor. However, since the available space is now much longer, the doctors are currently evaluating the need to obtain a new emergency incubator to be located at the other end of the corridor, since more time is taken to respond to emergency situations. This decision has a huge impact on the unit, as the cost of the incubator is very high and the budget is limited.

L-L. According to the interviewees, the new ECU offers more structure to work activities, with specialized working spaces, while affording more quietness, better awareness of the situation, and more fluidity and collaboration. The nurses reported lower coordination problems, although preserving the same level of communication that is necessary to handle emergency situations. Doctors now spend more time in the unit (Figure 3). The principal nurse is also more frequently in the unit. The other staff regarded this new situation very positively.

Furthermore, 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 (Figure 4). One negative outcome of this new arrangement is that by the end of the day, when the staff is reduced, the available nursing assistants work primarily in the cleaning room and thus leave the other rooms unattended.

L-S. The new environment also introduced some slight changes in the relationships between staff and rules and procedures, although more time is necessary to detect more profound changes (the new ECU was operating for only three months when the interviews were performed). One example of such a change is related to the nursing assistants. Since the nursing assistants are subject to high replacement rates 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 in the corridors, it has now moved to the working and dirty rooms, with a positive impact on the remaining activities (Figure 3).

The outcomes from this study showed the new working environment had a very positive impact on the overall organizational responsiveness and safety. The SHELL model facilitated the identification and assessment of the specific elements and causal relationships most responsible for the positive outcomes. Figures 3, 4 and 5 summarize these outcomes diagrammatically looking at the interaction between doctors and nurses (Figure 3), nurses and nursing assistants (Figure 4) and nurses and parents (Figure 5).

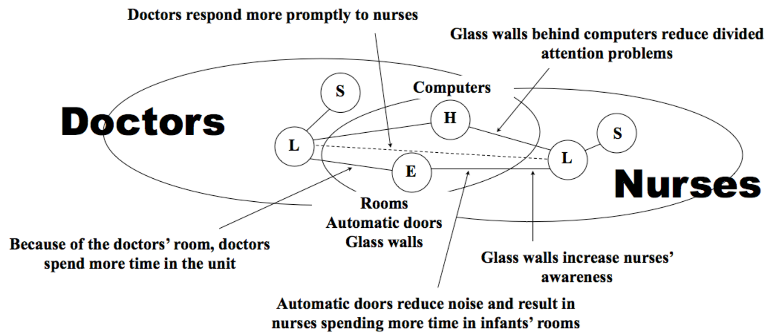

Figure 3. SHELL model details regarding doctors and nurses.

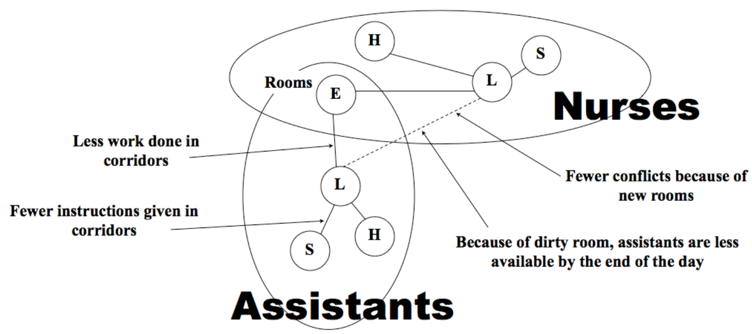

Figure 4. SHELL model details regarding nurses and assistants.

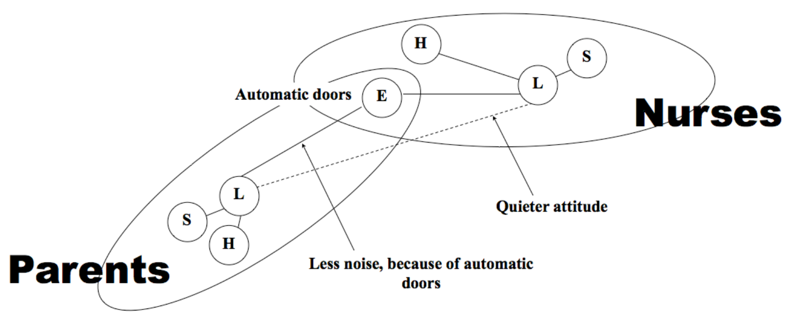

Figure 5. SHELL model details regarding nurses and parents.

From our point of view, the SHELL model served the set research goals well. Of course risk management is a very comprehensive endeavor and the case study collected qualitative data through interviews and observation and analysis. More extensive work is necessary to understand if the SHELL model also adequately supports other risk management activities in the health care domain.

Discussion and Conclusions

The SHELL model allowed us to obtain insightful data about the consequences of the installation changes that were done by the target organization. Of course, many of those changes were intended by design. For instance, the large glass walls and the principal nurse and doctors' rooms were intended to improve the ECU's structure and performance. However, as explicitly mentioned by the hospital management, there had not been any previous attempt to assess if the installation changes had the expected impact on performance. The results obtained showed a remarkable improvement in the overall work structure and workflow, with positive impacts on performance and safety. Regarding performance, we observed less coordination problems among doctors, nurses and assistants: the nurses and assistants have fewer conflicts because part of the assistants' work has been relocated to a specialized room; and the doctors have increased availability to respond to requests by nurses. Concerning safety, the fundamental outcome from this study was finding that nurses increased their presence and time spent in the infants' rooms and nursery; and they also have fewer attention problems when working on the computers.

The study showed that small technical decisions, such as deciding where computers should be located, might have a significant impact on the organization. But since the impact concerns Liveware-Liveware relationships, specialized analysis techniques focusing on collaboration issues are necessary to ascertain the causes and effects. The results also allowed the hospital management to report to other entities how and why the installation changes had an impact on the hospital unit.

The SHELL model allowed us to focus on the fundamental drivers of change when inquiring about the changes, and produce streamlined explanations of the causal relationships between the installation changes and the L-E, L-H, L-L and L-S model elements. Therefore one interesting outcome from this study is the positive role of the SHELL model in elucidating the intricate complexities of the work in the target organization, as well as the causal relationships that could explain what occurred after changing the installation. The SHELL model also demonstrated flexibility and plasticity to the varied situations that were encountered during the study.

One outcome of this study is that a small number of negative impacts or increased risks were found. Two major issues were found, one related to the increased distance between the emergency incubator and the infants' rooms, and another related with the decreased 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, we believe the increased presence of nurses in the infants' rooms was not deliberately designed, it just occurred as an indirect consequence of having doors separating the ECU and parents assuming a different attitude. The SHELL model was invaluable in pointing out these important consequences and the causal relationships explaining them.

The SHELL model was also invaluable in disentangling the collaborative nature of the work done in the ECU. The SHELL model has a strong focus on the liveware element, which naturally emphasizes the human aspects of the system under evaluation. But the model also emphasizes the L-L relationships, which were instrumental to elicit, analyze and describe what was happening with the collaborations in the work setting. As most of the positive outcomes coming from this study were coming from the L-L relationships (better work structure, more awareness of the environment and infants, increased presence, less conflicts between staff), we positively regard the role of SHELL in the analysis of collaborative work.

This case study thus had very positive results. From the hospital management point of view, this project was their first opportunity to address risk management with a focus on collaborative work settings. From our point of view, the SHELL model can be and should be used more often to assess collaborative settings in the health care domain.

We must nevertheless point out that risk management is a comprehensive endeavor, which was not completely covered by this research. Risk management encompasses not only the assessment of risks, but also forecasting and the definition of risk management plans.

The risk management approach in the health care domain is recent. Extensive research activities have focused on clinical issues, such as drug prescription errors, and hygiene issues. Many other research activities are addressing incident reporting and organizational adaptation and prevention (Barach, 2000; Evans, et al., 2006). There is little research concerning collaboration issues and risks arising from sub-optimal collaborative activities. This research contribution is a preliminary step towards bringing the CSCW view on risk management to the health care domain.

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