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Abstract. This paper describes a Human Factors Engineering approach to a medication use system in a context of a hospital medication CPOE project. It presents the results obtained from the organizational analysis and describes the variations in distribution of tasks between the actors of the medication use process, depending on the organization of the work system. It then focuses on nurses' medication administration tasks including the preparation and update of pills dispensers. This situation may be characterized according to the distributed cognition framework. The high level organizational features have an impact on the quality and safety of the coordination and communication procedures characterizing the nurses' medication preparation and administration tasks.

Keywords: Human factors, CPOE, medication administration, distributed cognition, process control.

1. INTRODUCTION

The Human Factors Engineering (HFE) approach to analysis, evaluation and redesign of the healthcare work systems has proven efficient [1]. This approach allows identifying the determinants of the work system that make the situation potentially dangerous. It also provides recommendations to secure and optimize this work system, on organizational, cognitive and technical levels.

This paper presents a case study of a Human Factors Engineering approach to a medication administration process in a large academic hospital, in the context of a medication Computerized Provider Order Entry (CPOE) project. We focus here more particularly on:

- The organizational level analysis, which describes the distribution of tasks between the actors of the medication use system, i.e. the physician in charge of the prescription, the pharmacist in charge of the dispensing, and the nurse in charge of the administration.
- The impact of the possible distributions of tasks on the nurses' activities of preparing and administering oral route drugs to the patients

The core task of the HFE approach is the analysis of the work system. It requires the understanding, description, analysis and if possible modeling of the work situation. It is possible to identify hierarchical levels in this work system [2]:

- The higher level, i.e. the organizational level is that of local and national regulations that impact all subsequent levels, mostly by prescribing the distribution of tasks across the professionals.
- The second level, i.e. the collective level is that of operators or groups of operators interacting with each other to collectively handle the healthcare process for a given patient. These collective characteristics of the care process generates both vertical, hierarchical cooperation (i.e. Doctor-Nurse cooperation) and horizontal, functional cooperation (i.e. nurse-nurse cooperation). It is also responsible of the distribution of medical information across different healthcare professionals and different technical systems or supports (paper and / or electronic documents). Similarly, knowledge and skills necessary to accomplish the tasks are distributed across different operators. This leads to the characterization of the healthcare work situation as a distributed system [3]. In this context, professionals are mutually dependant from each other: to obtain the right information at the right moment they have to share information efficiently.
- The individual level is that of the individual operator, the healthcare professional interacting with his / her technical environment to monitor the patient's clinical status.

The present paper focuses more particularly on the organizational level analysis, which describes the distribution of tasks between the actors of the medication use system, i.e. the physician in charge of the prescription, the pharmacist in charge of the dispensing, and the nurse in charge of the administration.

2. METHODS

2.1. Context of the project

The Centre Hospitalier Universitaire of Lille (CHU Lille) in the North of France is a 3000-bed-capacity hospital. This academic hospital is equipped with a Hospital Information System (HIS) integrating over 80 different applications, but no medication CPOE facility, nor specific nurses' documentation or other support functions such as nursing plan or Medication Administration Record (MAR), which are still paper-based. The hospital therefore envisions installing a CPOE system able to support all medication ordering – dispensing – administration tasks. The CHU Lille ordered and participated in a HF preliminary study to assess the state of preparedness of the CHU departments before the medication CPOE installation. In order to support the hospital managers' decision making, descriptions and organizational analyses of other hospitals already equipped with complete medication CPOE have been compared with the results of the analysis of the CHU Lille medication use system.

2.2. HFE methods

We performed a systematic qualitative analysis of the medication ordering - dispensing - administration process in several departments of the hospital. An analysis of nurses' tasks and activities, focusing on their cognitive and collective aspects was carried out. Organizational contexts and habits of work were also recorded. We used standard

methods from cognitive psychology and ergonomics: (1) Semi-structured and structured interviews of target users; (2) Naturalistic observations supported by handwritten time-stamped detailed field notes; (3) Documents review and charts review; (4) Confrontation interviews: nurses were presented with the results of observations and documents review performed in their departments and were asked to comment on and mentally replay the processes involved in the reading and interpretation of orders for the preparation of pills dispensers and for the administration itself; (5) Nurse-nurse dialogs during shifts changeover were recorded and analyzed.

3. RESULTS

3.1. Organizational level

According to national and local regulations, the tasks necessary to carry out the medication ordering and administration procedures are distributed across the physicians, the pharmacists and the nurses. The physician is in charge of the therapeutic decision making and of ordering the meds. He is supposed to write the prescription and to date and sign it. The nurse has no medication ordering rights except for a small number of usual drugs (i.e. standard painkillers) and only if a written protocol exists in the department. She/he's not supposed to copy the physician's orders on any support except to validate the administration. The pharmacist is in charge of controlling the prescription and of delivering the medications to the medical unit. The nurse has to control the meds before administering them to the patient; she must validate the administration and eventually document any unexpected event. It must be noted that in the vast majority of European hospitals, unit-dose dispensing is limited to a small proportion of drugs. Most of the drugs are dispensed either on a nominative basis (drugs for a given patient for a given period of 24h to several days) or on a global basis (drugs for several patients and for several days). This organization of the dispensing necessitates a preparation phase from ward stock before the actual administration to patients. Nurses are in charge of this preparation.

The analysis identified different organizations within the hospital. In order to describe and model the various organizations, we used adapted UML activity diagrams. Figure 1 displays one of these diagrams, modeling a paper-based work system. In this organization, the nurses participate in various tasks at each phase of the process.

Prescription phase: the nurses participate in the medical rounds with the physician(s). They (i) provide information on the patient (ii) gather information, may ask questions (iii) participate in the decision making, negotiate the care plan in anticipation of potential administration problems (iv) nurses are constantly eavesdropping on doctor-doctor and doctor-patient dialogs

Dispensing phase: the nurses (i) send nominative orders to the pharmacy (ii) order the drugs at the pharmacy and may dialog with the pharmacists or pharmacist assistants (unavailable drugs, or dosages, substitutes, etc.) (iii) retrieve the drugs delivered from the pharmacy, stack them in the ward locker (or in patients' rooms)

Administration phase: the nurses (i) prepare the drugs for administration rounds (preparation of pills dispensers) (ii) administer the drugs to patients, document the administration.

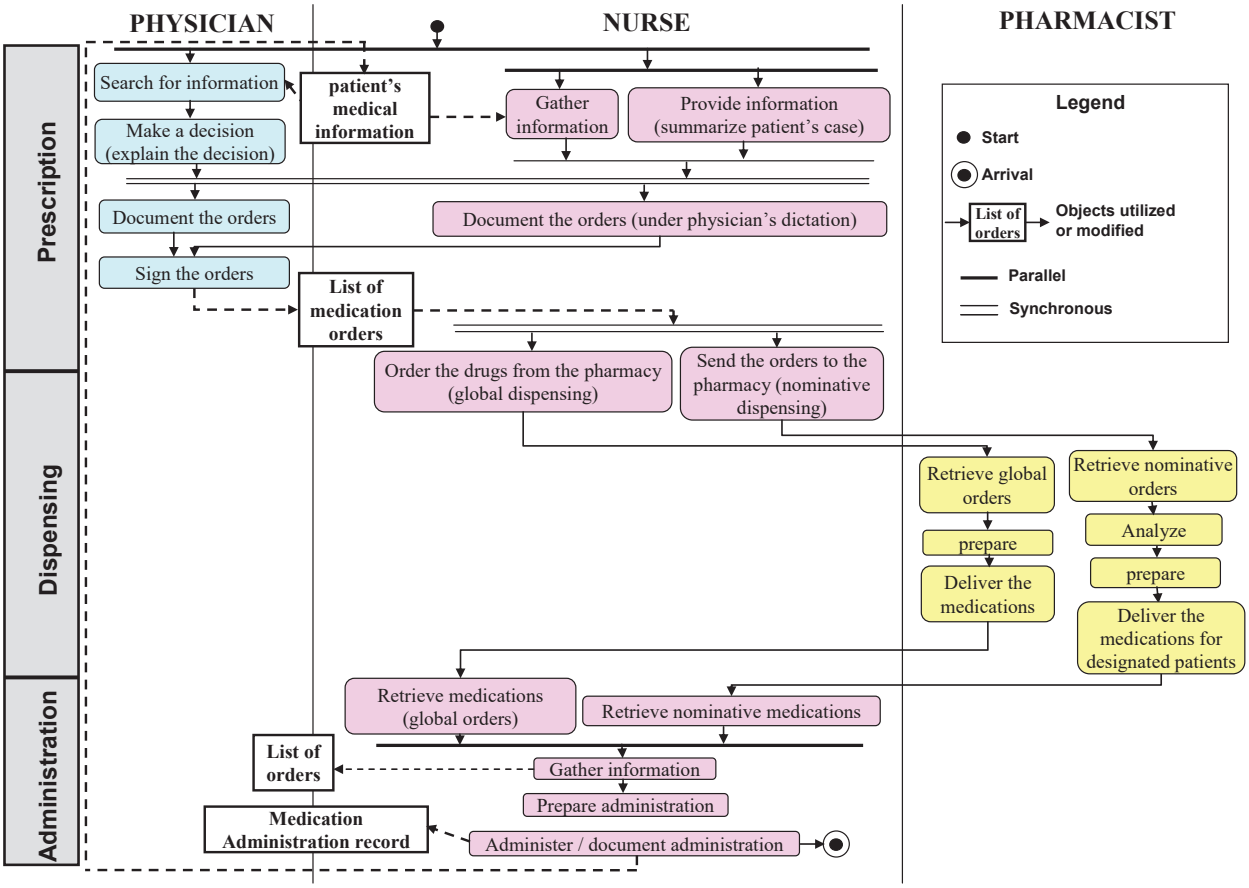

Figure 1: UML model of the distribution of tasks between the physician, the nurse and the pharmacist fro the medication use process in an observed paper-based organization

The organization modeled in figure 1 differs slightly from the organization one could expect from the description of national and local regulations: the nurses participate in many more tasks than those regarding medication administration.

The description and model of CPOE based organizations may prove very different: in those organizations, the CPOE system ensures the transmission of information between the actors, the pharmacist's control of the process is enhanced by his access to nominative orders and to the corresponding patient's medical record. As a consequence, the nurses' participation in the medication use system is more limited: they step in only for the preparation and administration of the drugs for the patients.

The analysis of the organizations observed in the different hospitals and departments allowed the identification of a number of organizational factors such as (non exhaustive):

- type of cooperation / communication between physicians and nurses (coordination devices): (i) common rounds (ii) briefings (iii) opportunistic
- speed of the patients' physiological and clinical process (i) type of unit: ICU; surgery, medicine, long stays (ii) frequency of medication orders update / modifications per day
- characteristics of the drugs used in the department (i) type of drugs (pharmaceutical classes frequently used in the department) (ii) type of dispensing: proportion of drugs on nominative vs. global dispensing (iii)proportion of injectable vs. oral route drugs

- type of technical system to support the tasks (i) paper forms (ii) CPOE

There is a large variety of possible combinations between those factors. For example each type of cooperation may be combined with the type of technical system or the type of unit, although some combinations are not frequent, like <common rounds and CPOE system>. In turn, these different organizations have an impact on the quality and extent of each actor's knowledge, on the distribution of knowledge and information across the actors and the technical systems and on the distribution of the control of the medication use process.

3.2. Collective level

The organization of the administration of oral route medications is structured by the preparation of 24 hours pill dispensers. At some point in the 24 hour period a nurse prepares the pill dispensers for all the patients of the ward. To perform this preparation, the nurse relies on the information contained in each patient's medication orders list as prescribed by the physician. This preparation takes place in the room where the ward medication cupboard is located, usually the nursing room. Each dispenser is identified by a room number and sometimes also with the patient's name

During the 24h period covered by the pill dispensers, the physicians visit the patients and place new orders or modify the existing patients' treatments. These modifications require an update of the corresponding pill dispensers by the nurse. This update is executed as soon as the nurse gets a modified medication orders list. Over this 24h time period, different nurses are in charge of updating the pill dispensers and administering the meds to the patients. This makes the whole procedure or workflow more complex as exemplified below.

BOX 1: Description of a of a typical organization of the medication preparation and administration workflow distributed over several nurses and several shifts

In this observed example, the night shift nurse (N1) starts her shift by administering the "bedtime" meds: after this last administration of the day, the pill dispensers are empty. She is then in charge of preparing the pill dispensers, which include four compartments for morning, noon, evening and bedtime administrations. The first nurse of the morning shift (N2) takes care of the first administration round of the day, after which the physician performs his medical round issuing modifications of existing orders or new orders. The same morning nurse N2 accordingly updates the pill dispensers. Then the second morning nurse (N3) takes care of the second administration round around noon. In the afternoon, a physician performs a rapid follow up of the patients, again issuing some modifications and new medication orders. The afternoon nurse (N4) takes care of the update of the pill dispensers, and then performs the evening administration round.

There are also at this level a great number of organizational factors that may vary: (i) the nurse in charge of the preparation of the pills dispensers may be the morning shift or the afternoon shift one; (ii) the meds of a given patient may be stocked in his room and be prepared only at the moment of the administration; (iii) Etc.

4. DISCUSSION AND CONCLUSION

The work system described in Box 1 is characterized by a distributed cognition organization. This situation requires efficient coordination and communication between (i) Physicians and nurses (ex: the transmission of new orders from physician to nurse enables the update of the pills dispensers) (ii) Nurses of different shifts (ex: shifts changeover oral transmission routines enable the control of the pills dispensers and the administration of the meds).

The higher level organizational features have an impact on the quality and safety of those coordination and communication procedures. For example, each nurse is a source of information for the physicians and for the other nurses. Depending of the organization, the quality and extent of her knowledge about the therapeutic care plans and about the drugs management in the hospital may vary greatly. For example, based on the analysis of nurses activities and confrontation interviews [4], we could establish that a nurse participating in medical rounds and in charge of ordering the ward medication at the pharmacy presents an extended understanding of the medical characteristics of the pathology, an extended knowledge and understanding of the therapeutic care plans and of their underlying medical rules and finally an extended knowledge of the particular patient's medical case. Plus she also has a good practical knowledge of drugs management. Conversely, a nurse whose tasks are limited to the administration phase presents a more limited understanding of the medical characteristics of the pathology, a more operational knowledge of the therapeutic care plans and a more operational knowledge of the patient's medical case.

It is therefore important to ensure that the organization imposed on the healthcare professionals participating in the medication use process is coherent, i.e. that the distribution of the control of the medication process is consistent with the distribution of tasks and with the resulting knowledge of each actor.

The distributed cognition framework completed by detailed models of existing or possible organizations proves very useful to support safe and efficient IT projects in healthcare. This approach provides the project team with structured descriptions of the current and / or expected work systems, and helps them understand the complexity of those work systems, deliberately design the future work system integrating a new IT application and (re-)design safer and efficient IT systems. It also helps both IT people and hospital managers understand that an IT project is much more than simply replacing the paper forms by computers. It helps understand that an IT system needs to be harmoniously integrated in the activity system to efficiently and safely support the propagation of accurate representational states.

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