Cognitive analysis of physicians and nurses cooperation in the medication ordering and administration process

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A B S T R A C T
The objective of this study was to analyse physician–nurse cooperation in the medication ordering and administration process from a cognitive point of view. In this paper, we compared two work organizations characterized by: (1) a synchronous cooperation engendered by common doctor–nurse medical rounds and (2) an asynchronous situation characterized by split physician’s and nurse’s rounds. Both organizations worked with paper-based documentation systems. We relied on a cooperation cognitive architecture model and used specific methods from cognitive ergonomics to analyse physicians’ and nurses’ activity, communications and cooperation.

The analysis of doctor–nurse dialogues during the medical rounds demonstrated that in the synchronous situation, the nurses actively participated in the medication ordering process. Such dialogues supported the elaboration of shared knowledge in the form of a common frame of reference (COFOR) which both actors rely on to control the entire medication process, and more precisely the coordination of their actions. Document analysis showed that the orders were far from exhaustively documented. However, self-confrontation interviews with the nurses demonstrated that, except for a small number of ill-documented orders, they were able to accurately retrieve the physician’s complete intended orders. In this work organization, the nurse was able to control the medication administration process at a high level, because she understood the highest level of strategic control of the medication ordering carried out by the physician.

In the asynchronous situation, the results were reversed. The nurses no longer participated in the decision making phase of the medication process. Doctor–nurse communications were rare, and their shared knowledge about the patient was weakened. Although written orders proved to be better documented, the nurses suffered from a lack of knowledge on the patient’s medical case and the particular context of the medical decision making when confronted with incomplete or ambiguous orders. In this work organization, the nurse would find herself restrained to low level process control and confined in a reactive, instead of anticipative, management mode. This latter work organization is very similar to the CPOE situation we observed in previous studies, where the coordination of physicians’ and nurses’ actions was delegated to the system. We suggest that it is essential to take these organizational and cognitive aspects into account when (re-)designing CPOE applications.

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1. Introduction

Information Technology is regularly cited as a means of improving the quality of the healthcare process and patient safety. This is particularly true for a subset of critical functions, such as medication ordering and administration [1–3], that can be supported by computerized physician order entry systems (CPOE). The basic assumption underlying this belief is that a better, more available, more exhaustive and more precise documentation efficiently prevents the risk of medication errors [4]. However, systematic surveys and qualitative studies from the socio-technical field [1,5–7] including cognitive psychology [8] and usability [9,10], show that the introduction of Information Technology in the healthcare process has dramatic effects on work processes, especially where physicians’ and nurses’ tasks are concerned. Although significant reductions of potential medical errors, such as adverse drug events (ADE) can usually be proven [11–14], a number of authors have expressed concern that the changes to the work organizations engendered by the introduction of IT-based systems may breed new errors that are difficult to anticipate and difficult to catch [15,5,16]. These authors insist on the necessity for detailed qualitative studies aimed at understanding the “epidemiology” of errors in these new organizations [17,5]. Others [5,18] stress the importance of an understanding of the transformation of the work processes and of the operators’ activities when the organization shifts from paper to IT systems for a critical set of functions. CPOE is a good example of such challenges. There is, thus, a need for detailed qualitative studies comparing the work situation in both environments, paper-based or IT-based.

In a previous work, we performed such a comparative qualitative analysis of the medication ordering and administration process [8,9,19]. We analysed the tasks performed by the physician, the nurse, the pharmacist, and, when available, the computer system (CPOE) in two different situations: (1) a paper-based situation and (2) in a CPOE environment. The results of this work are summarized in Figs. 1 and 2, which describe the distribution of tasks and activities among the actors participating in the process.

In the observed paper-based situation (Fig. 1), the physician was in charge of the medication ordering, but he benefited from the nurse’s presence during his medical rounds, gaining valuable information on the patient’s current status, as well as profiting from her explicit input into the selection of therapies. Indeed, the nurse was an active participant in the decision making phase. As she listened to doctor–patient and

Fig. 1 – UML modelling of the distribution of tasks and activities among the participants in the medication process in a paper-based and synchronous doctor–nurse cooperation situation.
Fig. 2 – UML modelling of the distribution of tasks and activities among the participants in the medication process in a CPOE and asynchronous doctor–nurse cooperation situation.

documents–doctor dialogues, she could understand the physician’s intentions underlying the orders. She was then in charge of sending to the pharmacy the orders requiring a nominative dispensing (around 20% of the orders) and of ordering from the pharmacy the products that are delivered as, and dispensed from, ward stock. She was thus very familiar with the pharmaceutical format of the medications available in the hospital and in the ward. After having retrieved the products, she prepared the distribution of medications for all the patients in the ward for the following 24 h. She administered the products to each patient during her rounds, or at specified times, depending on the medical orders. While this last task was specifically hers, she actively participated in the precedent tasks, having an overall extensive knowledge of the medication process and of its intended medical effects.

In the CPOE situation (Fig. 2), the physician was still in charge of the medication ordering, but as the nurse did not accompany him on his medical rounds, he relied mostly on the system (and potentially on information provided by house-officers if there were any) to get the necessary information on the patient’s status and current medications. The system was then in charge of transferring the orders to the pharmacy, who then dispensed the drugs on a nominative basis. So the only task the nurse was actually in charge of was to retrieve the medications, to prepare the distribution and to administer the meds and document this administration on her medication administration record (MAR).

The different distributions of activities in the two situations clearly resulted from an interaction between organizational choices and work devices. For example, a CPOE better supports a unit dose dispensing organization than a paper-based system. However, the most striking difference between the two situations concerns the doctor–nurse cooperation in the ordering phase of the process, which in turn is more or less a consequence of her participating or not in the medical rounds. The paper-based situation was characterized by a synchronous cooperation with a distributed decision making where physicians and nurses relied mostly on verbal communications to coordinate their actions. Paper order sheets were weakly structured and poorly supported the documentation task. In the computer situation, physicians and nurses were working in an asynchronous mode, and left to the system the coordination of their actions. In this context, verbal communications were much less important and less numerous, which observation is consistent with all the studies that have demonstrated the negative impact of CPOE on doctor–nurse communications [20,21]. Computerized orders seemed exhaustively documented, but there remains a serious question whether
the loss of synchronous verbal communication may not lead to critical misinterpretation of data [19].

Following the results of this first study, we can identify two main variables that structure the doctor–nurse cooperation in the medication ordering and administration process:

- First variable: the system for order entry, paper-based versus computer-based (CPOE).
- Second variable: the type of cooperation, synchronous (with common physician–nurses rounds) versus asynchronous (with split rounds).

This paper presents the results of a complementary study designed to specifically analyse the impact of the second variable (i.e. the type of cooperation: synchronous or asynchronous) on the doctor–nurse cooperation in the paper-based situation. This study was designed to gain a better understanding of the influence of work organization on the quality of this cooperation and ultimately on the coordination of actions and on the individual and distributed control of the medication process.

2. Theoretical background

In the medication ordering, dispensing and administration process, a cooperative work relationship is mandatory: administration cannot be performed by the nurse until the medication has been ordered by the physician and delivered by the pharmacy. In this situation, the cooperation between the physician who provides the orders and the nurse who supervises the administration is distributed, the perspective of each about the patient and the ordering process being different. According to Schmidt [22], this cooperative arrangement relies essentially on an integrative cooperation because the different competencies, knowledge and points of view are intertwined and integrated. Such a cooperative arrangement may serve several functions [23], such as the improvement of efficiency, the differentiation and combination of specialties, mutual critical assessment, and the confrontation and combination of perspectives. For Schmidt [22,23], "people engage in cooperative work when they are mutually dependent in their work and therefore are required to cooperate in order to get the work done". This dependence is not only "the interdependence that arises from simply having to share the same resources". It implies the articulation and the coordination of the respective activities of the different operators.

This concept of coordination is also emphasized by Falzon [24] who considers that a double synchronization underlies cooperative activities: a temporal and operative synchronization which allows coordination, and a cognitive one which serves to establish a context of mutual knowledge [25,26]. This double synchronization also appears in the cognitive architecture of cooperation proposed by Hoc [27,28]. We chose this latter architecture because (i) it was elaborated in order to design human–machine and human–human cooperation tools [29] and (ii) a method of analysis of cooperative activities follows from it. Fig. 3 presents an adaptation of this architecture adapted from Hélie and Loiselet [30] and Hoc [27,28]. It relies upon three levels according to temporal span and distance from the action: cooperation in action (goals, procedures and interference management activities, in the course of task execution, in real time and in the short term), cooperation in planning (management – elaboration or maintenance – of the shared representation, in the medium term), and meta-cooperation (high level of abstraction activities).

A central concept of this model is that of interference, which refers to the fact that "the effects of the action of one agent are relevant for the goals of another, i.e. they either favour the achievement or maintenance of some goals of the other’s (positive interference), or threaten some of them (negative interference)" ([31], p. 162). The coordination between actors relies on this management of interference which forms the cooperation-in-action level.
As shown in Fig. 3, interference management requires the sharing of task representations, of partners’ activities and of the goal to be reached. Most of the studies in the cooperation domain underline the necessity for the agents to have a shared knowledge, belief and representation structure [32,33]. G. de Terssac and Chabaud [25] call this shared knowledge structure, the common frame of reference (COFOR) which is “the sharing of competencies to prepare and perform an action; this sharing of competencies at the same time complements each individual’s representation of the task, and enables the adjustment of each individual decision considering the other’s knowledge” (pp. 128–129). This notion is close to concepts such as those of common ground [34], shared mental models [35], or shared situation awareness [36,37]. At this second level, called “cooperation in planning”, the first part of the cognitive synchronization is achieved.

The third level, the “meta-cooperation” one, also contributes to this synchronization. At this level are elaborated the different forms of knowledge (general, relative to the task, relative to the partners, etc.), which are used to manage the two preceding levels, and particularly to feed the COFOR (internal source).

Two main external sources of information may contribute to COFOR management, communication between actors and observation of actions. In such cooperative situations, the sharing of the work space and of the information space is also essential. For example, when the nurse accompanies the physician on the daily medical rounds, they both access the same information. The nurse can also be a source of information for the physician, and each actor can interfere with the other in order to be as effective as possible. In this situation, communication is essential as (i) a support for the transmission of information necessary to the task execution, (ii) a support for team coordination and (iii) a means of COFOR management (elaboration and maintenance).

In the medication ordering and administration process, critical components of cooperation would be the synchronous oral communications that support the sharing of task representation, and easy simultaneous access to the patient’s record, that supports the sharing of the work space and of the information space. Based on the above framework, we carried out an extensive analysis of the doctor–nurse communications during medical rounds combined with an analysis of orders documentation by the physicians and orders interpretation by the nurses when they have to plan and execute medication administration.

3. Methods

We performed a qualitative analysis of the medication ordering and administration process in several departments of two different hospitals using paper-based orders.

The first observation site (Site 1) is the University Hospital of Lille in the North of France, which is a 3000-bed capacity hospital. In this academic hospital, the physicians are hospital-based professionals; up to 30% of the medical staff may be house-officers. Users’ activity was analysed in the Neurosurgery department, where the nurses accompany the physicians for their medical rounds (synchronous cooperation) and in the Cardiology department, where the nurses never accompany the medical rounds (asynchronous cooperation).

The second observation site (Site 2) was the Denain public hospital which is a 413-bed hospital located in the North of France. Approximately 100 physicians work in the hospital, along with 200 nurses. Forty-four percent of the physicians are hospital-based professionals, 56% are part time. In this hospital, users’ activity was analysed in two different departments: Respiriology, where physicians and nurses work synchronously, and Convalescence, which is an asynchronous situation.1

We carried out a task and activity analysis of physicians’ and nurses’ activities, focusing on cognitive and collective aspects. Organizational contexts and habits of work were also recorded. To perform the activity observation and analysis, we used standard methods from cognitive psychology and ergonomics:

- Semi-structured and structured interviews of target users (physicians, nurses and head-nurses).
- Participant observations focused on physician–nurse dialogues about medication, particularly during the hospital medical rounds, and on users’ interactions with patient records.
- Some rounds were audio-taped, allowing a protocol analysis of the doctor–nurse communications and actions during these rounds.
- Document analysis: in several department of both hospitals, we selected all the paper files of the patients present on a given day and we made copies of the physicians medication order sheets and of the nurses medication administration records (over 900 orders extracted from 119 patients’ files). These written orders were then analysed on a quantitative and qualitative basis.
- Self-confrontation interviews: nurses were presented with sets of written medication orders collected in their departments and were asked to comment on and mentally replay the processes involved in the reading and interpretation of orders for the planning of medication administration.

The present study focuses on the analysis of doctor–nurse dialogues during the medical rounds, on the quantitative and qualitative analysis of orders documentation and on nurses’ interpretation of these orders.

4. Results

4.1. Analysis of physician–nurse dialogues

The main interest in using a model and coding scheme is that it allows qualitative and quantitative comparisons between different work situations.

We present here preliminary results from the analysis of physician–nurse dialogues recorded in the two departments

1 In this particular department, physicians and nurses shifted from a synchronous to an asynchronous cooperation mode just before the observation started.
of Site 1: Neurosurgery (synchronous) and Cardiology (asynchronous). In both departments, two medical rounds were exhaustively recorded. Then, all the physician–nurse communications about medication during 2 full days’ observation were also recorded.

We selected in the dialogues all the physician–nurse communications pertaining to the patient’s care and his medications. Table 1 summarizes the number of relevant communication units in the two departments and their context of appearance.

In the synchronous situation, physicians and nurses shared all the necessary information during the common rounds, and the nurses had no need to return to the physician to carry out the orders. In the asynchronous situation, the nurses did not participate in the rounds and they tried to get the physician when he happened to be available if they needed any clarification about the orders. In this situation, doctor–nurse communications were scarce.

The qualitative analysis of these doctor–nurse dialogues allowed access to the first two levels of the cooperation cognitive architecture displayed in Fig. 3:

- The interference management, which refers to cooperation in action.
- The common frame of reference (COFOR) management, which refers to cooperation in planning.

In order to illustrate our analytic method, we present in Fig. 4 a typical excerpt of a dialogue during the medical round in Neurosurgery. The analysis identifies the “cooperation units” each of which refers to one of the different classes of cooperative activities, cooperation in planning and cooperation in action. In each category, we can identify two subcategories: “COFOR management” or “Plan management” for

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**Table 1 – Distribution of communication units in the doctor–nurse dialogues according to the work organization (synchronous vs. asynchronous) and the context of appearance of the dialogues referring to patients’ care and medications**

<table>
<thead>
<tr>
<th></th>
<th>Medical rounds</th>
<th>Other contexts of appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous (Neurosurgery, common rounds)</td>
<td>417</td>
<td>0</td>
</tr>
<tr>
<td>Asynchronous (Cardiology, split rounds)</td>
<td>0</td>
<td>34</td>
</tr>
</tbody>
</table>

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**Fig. 5 – Distribution of communications units in doctor–nurse dialogue, according to the cooperation mode considered, synchronous (Neurosurgery, n = 417) vs. asynchronous (Cardiology, n = 34).**
Cooperation in Planning, and “Interference Creation” or “Interference Detection” for Cooperation in Action.

In the verbal exchanges displayed in Fig. 4, an example of a “negotiation” between the two actors appears.

The distribution of the physician–nurse communication units in both synchronous and asynchronous situations shows interesting contrasted patterns.

Fig. 5 shows that in the synchronous situation over 80% of the dialogue is dedicated to cooperation in planning. This confirms the importance of COFOR management in the dialogues, and the important part played by the nurse in the planning of the medication process and in the ordering phase of this process. In the asynchronous situation, the results are reversed: coordination of actions amounts to 60% while COFOR management (cooperation in planning) represents only 40% of the communication units.

If we consider the functions of the communication units (Fig. 6), other interesting information appears. In the synchronous situation, over 80% of communications units are dedicated to information management and to representation updating, (requirement for information + answer to requirement + transmission of information), as illustrated in Field Note 1 (Box 1).2

In the synchronous situation, requirements for information are initiated principally by the physician, but the nurse may also ask questions. As a consequence, answers to information requirements are mainly nurses', but around 10% of the units are physician’s answers to nurse’s questions. Almost 40% of

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Box 1: Updating the doctor on a patient's case by the nurse

**Context:** As they enter the patient’s room, the doctor is examining the scan the patient had that morning. The patient had several episodes in which she complained of feeling unwell the previous evening. The nurse transmits the information to the doctor and answers his questions.

**Nurse (RN):** She complained of feeling unwell at times; they even had to call Dr. X (the duty doctor). She really wasn’t doing well.

**Doctor (MD):** Unwell how?

**RN:** Face flushed, palpitations. I think her BP [blood pressure] was up to 160 yesterday noon. She usually runs around 110 or 120... (to the patient): why don’t you tell the doctor yourself?

**Patient (Pt):** Yesterday evening I just didn’t feel well. They changed my IV, and then I ate, and after I ate I began to feel sick.

**RN:** She associated it with taking her Perfalgan® [paracetamol], but it didn’t happen afterwards when you took the Perfalgan®? (to the patient)

**Pt:** No, no, I took them several times.

**MD:** Who was it came?

**RN:** It was Dr. X who came and listened to her chest.

**MD:** Good, OK.

**Head Nurse:** And after that she was normal.

**RN:** Yes, now everything is fine.

**MD:** Good!
Box 2: Facilitation of nursing tasks (1)
Context: following a patient’s remark, the nurse suggests a management which the doctor adopts. She also suggests an alternative medication because the original choice is not stocked in the pharmacy.
Pt: I can’t bring anything up.
MD: You can’t bring anything up?
Pt: Yes, and it’s hard for me to spit, especially with my throat hurting so bad.
MD: It’s hard?
Pt: It’s horrible.
RN: We could do chest physio, couldn’t we?
MD: Yeh, we could do chest physio, with Lysopaine® [bacitracin] or something.
RN: We don’t have that.
MD: You don’t have it?
RN: Apltoral® [chlorhexidine, tetracaine].
MD: Fine, give her that.
Facilitation of nursing tasks (2)
Context: The nurse suggests an immediate change of antibiotics to the oral route because she is having difficulty getting an IV. The doctor decides to wait a bit, but he proposes a solution for the next time (next similar patient’s case)
MD: Tomorrow he goes for a scan, right?
RN: Brain scan tomorrow, yes, we’ll switch?
MD: Switch? What?
RN: This (showing him the IV).
MD: Wait, not yet; we have to see the scan tomorrow first. It’ll be three weeks, Saturday, right? We’re only at day 20 and they said three weeks of IV [in ICU], but it depends also on what the scan shows tomorrow. We might be able to change …
RN: So we’ve got to stick him again!
MD: Well, yes.
RN: Look, every day we stick him. You should see his arms. Three weeks of antibiotics, he’s got no veins left. They’re all shot, and now it’s even a problem getting blood for blood tests.
MD: OK, the next time we have somebody with an abscess, we’ll get a central line put in.
RN: Yeh, OK, … but you should see what a mess he’s in!
MD: OK.

the communication units concern information spontaneously provided by each actor. A content analysis of these units shows that the physician pays attention to the nurse’s understanding of his orders. He usually makes sure that she understands the purpose of the orders. Not surprisingly, the medication ordering is performed almost exclusively by the physician, but the nurse contributes suggestions, eventually to facilitate her own subsequent administration task, as illustrated in Field Note 2 (Box 2).

In the end, in this synchronous situation, the therapeutic decision making often appears to be collegial, as illustrated in Field Note 3 (Box 3).

In the asynchronous situation, the results are once again reversed: the requirement for information is mainly the nurse’s, and the physician provides the nurse with more information than he gets from her. The decision making about medications no longer appears in the dialogues, nor are there suggestions from the nurse in this domain. The rare nurse’s “decision making” items refer to requirements for doctor’s actions, as illustrated in Field Note 4 (Box 4).

Coordination of actions between physician and nurse is obviously supported by oral communications, but the written orders are also important in this regard. To explore this aspect, we performed a qualitative and quantitative analysis of a selection of orders copied from the four departments studied in Sites 1 and 2.

4.2 Document analysis

4.2.1 Available information
Nine hundred and seventy-seven written medication orders were analysed. These were oral route orders from four departments of both Site 1 (Lille) and Site 2 (Denain).

Synchronous situation:
- Site 1 Neurosurgery, 109 orders for 20 patients, mean length of stay = 6 days.
- Site 2 Respirology, 292 orders, 42 patients, mean length of stay = 9 days.
Box 4: Nurse’s requirement for doctor’s action

**Context:**
Earlier the resident was making his rounds, while the nurse organized her blood samples for lab tests at the nursing station. The physician was looking for an X-ray on one of his patients and asked the nurse if it had arrived on the ward. When she replied in the negative, he asked her to let him know when it did. Later, when the nurse was making her medication administration rounds, one of the patients expressed surprise that he did not have his diabetic medication. The nurse checked in his chart, and noted that nothing had in fact been ordered. At that moment the X-ray arrived, and the nurse went looking for the physician to give him the X-ray, at the same time taking the chart of the diabetic patient with her.

RN: (handing the X-ray to the doctor) You have to prescribe something for the diabetic in Rm. 25.
MD: Rm 25 ... ah, yes!
RN: Ha! You forgot!
MD: Give me his chart. What does he take?
RN: Glucor® 100 [acarbose].
MD: (scribbles the order) Here!

**Asynchronous situation:**
- Site 1 Cardiology, 159 orders for 19 patients, mean length of stay = 5.5 days.
- Site 2 Convalescents, 417 orders, 38 patients, mean length of stay = 17 days.

We recorded all the data elements available in the orders. The analysis of orders content reveals that much of the information that would be mandatory or available in a CPOE system – frequency of administration, number of tablets per administration, total number of tablets per day, concentration of medication per tablet, total daily dose, route of administration, pharmaceutical form, administration schedule, exact time schedule for administration, duration, specific condition for administration – is rarely recorded on the paper sheets.

Fig. 7 summarizes the percentages of available data elements in the 977 orders, 401 from the synchronous situation and 576 from the asynchronous one. Duration and exact time for administration are so rare as to be virtually nonexistent. The administration schedule ("morning", "noon", "at bedtime"), the route, the form and even the dosage (total daily dose and concentration of medication per tablet) are missing in over 50% of the orders. The number of doses per day (frequency) and the unit or quantity per dose is missing in over 40% of the orders. Overall, orders written in the asynchronous situation appear to be better documented than orders coming from the synchronous situation. To account for these differences we undertook a qualitative analysis of the patterns of available and missing information in the orders.

4.2.2. Patterns of missing information

We analysed the completeness of each order dosage, which is a combination of the following data: frequency of administration, number of tablets per administration, total number of tablets per day, concentration of medication per tablet, total daily dose. Total number of tablets to be administered in a given 24h period may be directly documented, as in “three tablets a day”, or indirectly, as in “two tablets at 08:00 a.m., one tablet at noon”. Similarly, the total daily dosage may be directly available as in “Medrol® [methylprednisolone] 50 mg” or readily calculated as in “Atarax® [hydroxyzine] 25 mg x 3”.

We recorded each of these data elements as available (code = 1) or missing (code = 0), in each order. A pattern was then defined as a combination of available and missing data constituting a complete description of the orders. Only the patterns present in over 2.5% of the orders were considered (two patterns, 33 orders discarded). The resulting patterns are described in Table 2.

In pattern P1, orders are scarcely documented: except for the name of the drug, there is no information at all about the dosage, the quantity nor the frequency of administration. In these orders, only the name of the drug is available, as in “Normacol® [sodium phosphate enema]” or “Imodium® [loperamide].

Pattern P2 comprises orders in which only the frequency of administration, or the total number of tablets per day or the...
total daily dosage is documented. This pattern is encountered in orders such as “Dafalgan® [paracetamol] three times a day”, or “Stablon® [tianeptine] 3/day” or “Medrol® 50 mg”.

In pattern P3, the number of tablets per administration and the frequency of administration are documented, making the total number of tablets per day clear, but the concentration of medication per tablet and the total daily dosage are missing, as in “Cordarone® [amiodarone] 1-0-0” or “Coversyl® [perindopril] one pill in the morning”.

In pattern P4, on the contrary, the concentration of medication per tablet and total number of tablets per day are documented, making the total daily dosage available, but the frequency of administration and the number of tablets per administration are missing, as in “Kaleorid® [potassium chloride] 600 2/day”.

Note that in each of these four patterns, the nurse is required to supply the missing detail needed to translate the order into concrete medication administration. Only in Pattern 5 are all the data necessary to fully define the medication order available.

The distribution of these patterns among the orders is presented in Fig. 8.

Pattern P1 is (fortunately) the least frequent, representing about 5% of the orders. A content analysis of these orders shows that they address mainly intestinal transit problems, sore throat or non-severe dermatological problems. Such medications as laxatives may be in daily use for a great number of patients in the hospital setting, and are usually not subject to detailed documentation. However, such orders as “Lexomil® [bromazepam] if necessary” may remain potentially difficult to administer properly.

Pattern P3, in which the concentration and total dose are missing, is a frequent pattern in both situations. These orders often correspond to medications for which only one concentration is available (or used) in the department.

Orders documented with only a total quantity or total dose per 24 h (P2) are the most frequent pattern in the synchronous situation, while the more exhaustively documented (P4 or P5) orders are more frequently encountered in the asynchronous situation. These results support the hypothesis that orders are qualitatively better documented in the synchronous situation. This context is that it makes it possible to access the third level of the cooperation cognitive architecture displayed in Fig. 3, i.e. the meta-cooperation level. By having the nurses verbalize the knowledge they rely on to execute each order, we should be able to access their models of their partners, of themselves, of the task, and of communication codes. In this case, the content of the nurses’ answers to our questions should accurately reflect the knowledge on which they rely to interpret and carry out orders lacking in necessary detail.

Several nurses from the Neurosurgery (synchronous) and the Cardiology (asynchronous) departments were confronted with several written orders representing Patterns 1–4. For each order, they were asked to explain how they would carry out the order, and exactly what would be given to the patient and when. The nurses were then required to detail the knowledge on which they would rely to fill in the missing data. These interviews were exhaustively recorded and transcribed. A content analysis was then performed by two coders who first identified each information unit and then categorized it according to the type of knowledge it referred to.

Three hundred and forty-nine information units (synchronous $n=217$, asynchronous $n=132$) were identified and then categorized. Table 3 displays the general categories derived from the content analysis, and provides an example of an information unit for each category as well as the percentage of unit communications pertaining to this category for both situations.

The results show that for most of the orders with missing data, and in both synchronous and asynchronous situations, the nurses rely mostly on their knowledge of the task to be carried out. This is a procedural, operative knowledge of the

### Table 2 – Observed patterns of available or missing data in the 977 written orders

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Total daily dose</th>
<th>Concentration of medication per tablet</th>
<th>Total number of tablets per day</th>
<th>Number of tablets per administration</th>
<th>Frequency of administration</th>
<th>Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>P4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

0, missing data; 1, available data.

Fig. 8 – Distribution of the patterns of missing/available data among the 944 orders from the two “synchronous departments” (Site 1 Neurosurgery, Site 2 Respirology and the two “asynchronous departments (Site 1 Cardiology; Site 2 Convalescents).
medication in use in the department and of the usual notation for orders documentation. When this category of knowledge is not sufficient to interpret and carry out the medication order, the nurses mobilise knowledge provided by their mental models of self and of partners. In the asynchronous situation, the mobilisation of this kind of knowledge is more frequent. However, a detailed content analysis shows that nurses working asynchronously refer mainly to knowledge of their own competencies and strategies, and almost never to knowledge of the physicians’ habits of work. In the synchronous situation, this pattern is reversed and the nurses refer abundantly to the physicians’ role and habits of work. The last category of knowledge which proves useful to interpret medication orders during the self-confrontation interviews demonstrate that both actors have good general knowledge of the patient’s case and his particular context of use, of the physicians’ role and habits of work. The last category of knowledge which proves useful to interpret medication orders is the contextual knowledge about the patient’s case and the physician’s medical decisions about this patient. This contextual knowledge is constitutive of and issued from the common frame of reference created by the synchronous doctor–nurse cooperation. Not surprisingly, it is much more frequent in the synchronous than in the asynchronous situation.

It must be noted that in the synchronous situation, despite what one would anticipate, the missing detail in the vast majority of the orders examined generally posed no problem for the nurses asked to replay their interpretation of the orders during the self-confrontation interviews. The nurses were confident of their ability to accurately retrieve the physician’s complete intended prescription, and by contrast, identify those instances where they were unable to do so, and needed to seek clarification. On the contrary, in the asynchronous situation, we observed that the nurses were anxious about the possibility of not being informed of the changes in current orders; moreover, they felt uneasy in the interpretation of the intentions and context of some of the medical orders.

5. Discussion

One of the objectives of this study was to test, adapt and customize a set of methods from cognitive ergonomics to study physician–nurse cooperation in the medication ordering and administration process, using a given model of cognitive architecture cooperation [27,28,30]. With respect to this objective, the methods used here proved to be relevant, efficient and, more importantly, well accepted by healthcare professionals, because they are minimally intrusive.

The main advantage of this combination of methods and cognitive model of cooperation is its focus on human–human and human–organization interactions. The term “organization” refers to a combination of other humans and their work systems, whether paper-based or computer-based. The present qualitative study shows that the work systems cannot be assessed independently of their context of use, of the characteristics of the organization they are embedded in, and of the cognitive cooperative activity they support.

The synchronous organization observed here is characterized by a physician–nurse cooperation that relies on the three levels of the cognitive architecture model of cooperation (Fig. 3). The analysis of doctor–nurse dialogues combined with the nurses’ self-confrontation interviews demonstrate that both actors

<table>
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<th>Categories of knowledge (meta-cooperative level)</th>
<th>Observed frequency</th>
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<tr>
<td>Task’s mental models</td>
<td>Synchronous (Neurosurgery) 51%</td>
<td>Knowledge of medication: usual dosing for a given pathology and rules of administration</td>
<td>“It is always one dose in the morning” “It is always 100 mg pills that we divide in two or four”</td>
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<td></td>
<td>Asynchronous (Cardiology) 51%</td>
<td>Knowledge of orders documentation: usual codes for notation and transcribing</td>
<td>[2/Day] “twice a day, it means morning and evening, otherwise the doctor would specify”</td>
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<tr>
<td>Mental models of self and of others</td>
<td>Synchronous 28%</td>
<td>Knowledge of her own competencies</td>
<td>“I have not enough information to execute this order”</td>
</tr>
<tr>
<td></td>
<td>Asynchronous 43%</td>
<td>Knowledge of nurses strategies (cooperative or individual)</td>
<td>“A nurse would have to phone the doctor”</td>
</tr>
<tr>
<td>Contextual knowledge</td>
<td>Synchronous 21%</td>
<td>Knowledge of the patient’s case and his particular context</td>
<td>“He [the patient]’s already on medication at home, he needs his usual meds”</td>
</tr>
<tr>
<td></td>
<td>Asynchronous 6%</td>
<td>Knowledge of the medical decision making</td>
<td>“This treatment depends on two parameters; when they are met, we may suggest a shift from the intravenous to the oral route”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exceptions: when rules do not apply</td>
<td>“The patient is NPO [fasting] so should not get it [the medication] orally, but the anaesthetist explicitly ordered it, so it is OK”</td>
</tr>
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</table>
rely on shared representations to coordinate their actions and to manage the entire medication process. These critical shared representations and knowledge are supported by the combination of (i) verbal communications and (ii) written documentation of the orders and of their administration.

In this situation, the nurse is able to control the medication administration process at a high level. She understands (or at least is aware of) the highest level of strategic control of the decision making and medication ordering carried out by the physician. She is able to manage the tactical and operational levels of process control. She is therefore in a position to catch potential medical errors at both levels.

On the contrary, in the asynchronous situation, verbal communications are scarce and the shared representations are weakened. On the other hand, orders are more completely documented and the patterns of collected documents are more exhaustive. Nevertheless, the self-confrontation interviews demonstrate that the nurses suffer from a lack of knowledge on the patient’s medical case and the particular context of the medical decision making. This situation makes doctors’ orders more difficult to interpret or to complete in case of non-exhaustiveness.

The present study demonstrates that the organization of the work situation has a considerable impact on the contextual knowledge which nurses and doctors rely on when they carry out their tasks, and consequently on the coordination of their actions. While a reciprocal knowledge of each other’s decision making and actions is embedded in the synchronous cooperation, this is no longer true in the asynchronous situation.

In our previous work focused on an asynchronous CPOE organization [8,9,19], we made similar observations: the responsibility of the coordination of actions was delegated to the CPOE system. Therefore, nurses and physicians were not obliged to elaborate and maintain a rich common frame of reference, as the main utility of this COFOR is precisely to support the coordination of actions (interferences management). This weakened physician–nurse cooperation might lead to (un)expected negative consequences. No longer having access to the physician’s intentions, the nurse might also miss parts of the medical purpose of the orders; she would no longer be able to control the medication administration process at a tactical level and her capacity to anticipate might also be considerably diminished. She would find herself restrained to low level process control and confined in a reactive, instead of anticipative, management mode. Such a hypothesis must be supported by further experimental and qualitative studies in the CPOE situations. Therefore, this research is currently being extended to other work organizations combining:

- a CPOE system and asynchronous cooperation (split physicians–nurses rounds);
- CPOE with common rounds. (This last combination might be more difficult to find in the field.)

6. Conclusion

The cognitive ergonomics methods used in this study, combined with the cognitive cooperation architecture model proved to be useful, efficient and acceptable by healthcare professionals. Our results raise some interesting questions about the impact of work systems, whether paper-based or computer-based, on physician–nurse cooperation in the medication ordering and administration process. The characteristics of the cooperation may in turn influence the quality of the process control assumed by the nurse and the physician.

More observations and analyses are obviously necessary in organizations working with CPOEs, but nevertheless some high-level recommendations can already be derived from the present study.

6.1. Organizational recommendations

Buying and installing a CPOE system is not just a matter of technology, it must be thought of as an interaction between an existing organization and the characteristics of the new system or work device. Hospitals or departments working asynchronously could benefit from the well-documented orders provided by a CPOE system. But for departments working synchronously, the benefit is more questionable, given the fact that the installation of a CPOE often results in a shift from synchronous to asynchronous mode. However, this depends only upon organizational decisions. When properly informed about the potential consequences of their organizational choices, project managers, head nurses and physicians representatives prove able to maintain or invent work organizations benefiting from both CPOE capabilities and the synchronous cooperation mode [19].

6.2. Design or re-engineering recommendations

Our results prove that the main benefit from the synchronous organization is the shared contextual knowledge between the physician and the nurse about therapeutic decision making. This is lost in the asynchronous situation, but existing CPOEs could not compensate for this loss of information or knowledge, given their rigid linear model of the work process and of the task allocation between the physician, the nurse and the system itself.

We suggest that CPOE designers take these results into account, in order to design and develop systems that actually support physician nurse cooperation in any work environment, instead of replacing it.

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References


