

Providing awareness through situated process maps: the hospital care case

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ABSTRACT

Clinical Pathways (CPs) are artifacts that clinicians are increasingly introducing in their practices in order to deal with health problems in the most effective, efficient and agreed way. As a result of an observational study at a Neonatology Intensive Care Unit, we identified that most CPs are still paper-based. Although perceived useful even on paper, the physicians advocated a system integrating CPs with the clinical record. Basing on their requirements, we present a proposal on how to conceive a computational system that can promote awareness so as to achieve a better coordination and committed pathway inclusion in daily clinical practice.

Categories and Subject Descriptors

H.5.3 [Information Technology and Systems]: Information Interfaces and Representation — *Group and Organization Interfaces*, *Computer-supported cooperative work*

Keywords

clinical pathways, cooperative work, collaboration awareness, hospital work

1. BACKGROUND AND MOTIVATIONS

The intrinsic limits of “models of action” in determining the course of situated action are well acknowledged in CSCW literature from the seminal contribution by Suchman [20]. On the other hand, the course of situated action is not invented from scratch in any given situation: it is rather based on a kind of knowledge, let us say it “procedural knowledge”, that is made explicit (i.e., “modeled”) at various degrees in order to become a common reference point and contribute to an effective course of action in distributed collaborative settings. These models can be intended as either *maps* supporting orientation and overview, or *scripts* supporting the compliance to pre-computed procedures along which work can be planned and accomplished [18]. This twofold role

holds for both the *modeler*, i.e., whoever makes the pre-computation, and the *doer*, i.e., the actor that interprets the model, performs actions in a certain context accordingly and is responsible for them. For this reason, this twofold role can raise a tough conflict of interest especially, but not exclusively, when it is experienced by the very same person, depending on the role she is currently playing: either that of “manager” (i.e., planner of her as well as of others’ work) or that of “practitioner” (i.e., actor in the field of work). Similar situations are even more accentuated in the clinical domain, where the possible divide between process maps and the “territories” of the temporal, spatial and contextual aspects of situated action can lead to either “inapplicable models” or “unjustifiable actions”. In fact, in medicine, the main object of consideration – the single patient and her illness – is something quite tough to classify (*diagnosis*) and quite unpredictable in its behavior (*prognosis*) when reacting to clinicians’ interventions (*therapy*). The manager-practitioner dilemma deeply characterized the hospital setting we studied with the aim to understand the way and extent procedural knowledge, clinical knowledge and clinical context can be combined and integrated towards a better support for situated clinical practice. Yet, this situation is pretty common – and our findings generalizable – since similar problems can arise where the very same artifacts are used for different and even conflicting purposes: namely, either to support individual decision making and coordination of care activities, i.e., what is also called the *primary* purposes of clinical documenting; or to facilitate the improvement of the quality of clinical practices, i.e., the *secondary* purposes of documentation [5, 11].

In this paper, we focus on a particular artifact, namely the process map that is called *clinical pathway*¹ (CP for short). In specialist literature, several definitions of CP have been given: in what follows we conceive of a CP as a “*map*” -i.e., *a schematic representation of a plan of preferred activities to undertake for the management of a homogeneous population of patients associated to a specific diagnosis from start to finish of their episodes of care* [1, 17]. CPs are rather new tools that doctors and nurses are beginning to become familiar with and whose use is often promoted by hospital managements for a number of reasons: i.e., better legal accountability, medical evidence retention, quality control, resource planning and smoother coordination. Besides in management policies, CPs are tools that even doctors seem

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¹Other authors refer to CPs as critical pathways, care maps, care programs, integrated care pathways and the like.

to advocate and accept [15] in their daily work, mainly because they are built collaboratively to achieve better quality of care, continuous learning and improvement, and better coordination with heterogeneous actors involved in the same clinical case.

While in case of clinical records both the primary and secondary use is well acknowledged, clinical pathways are mainly presented and characterized from the perspective of their secondary use. However, as soon as they enter in the everyday practice, the primary use comes upfront too, along with the conflict described above. We experienced the conflicting nature of CPs when we got involved into understanding, along with physicians, which role CPs play in current clinical practices, i.e., if and how CPs are used as tools that facilitate physicians' situated work. Since spring 2006, we have been collaborating with some clinical practitioners, both doctors and nurses, from the Neonatology Intensive Care Unit (NICU) of one of the most important teaching hospital in Italy. In particular, we had the opportunity to study the definition and use of clinical pathways within the daily activities at NICU. We soon realized that this investigation was strictly related to the initial goal of carrying on a feasibility study for the introduction of an improved version of an electronic clinical record that would be specific in dealing with NICU cases, without disrupting the current work habits of clinicians. According to practitioners, the main requirement regarding this improvement was to augment clinical records to convey to physicians the knowledge pertaining to the work context in a way that makes this knowledge useful and usable: CPs were obviously part of this picture. More than that, CPs became the main focus of attention since their conflictual role generated several lively discussions between the practitioners and our research team about the need for and nature of a technology supporting clinicians in using CPs profitably. We believe that it is worth reporting on this phase of our research effort, even if the actual design of a full prototype is not completely achieved and consequently no full evaluation of the envisaged solution has been completed. In fact, during this phase we had an unique experience (at least for us) of the role that we were called to play: sometimes to promote solutions to fulfill requirements, sometimes to strongly contrast some required functionality by bringing in the stratified experiences of failures that as researchers we know about. Whether this story reflects a canonical way to conduct field research it is not the main point: the outcomes were, on the one hand, a shared and deeper understanding of the implications, in the practice, of the twofold role of CPs; and, on the other hand, a set of partially evaluated design choices that will guide the subsequent phases of technology development.

The paper is organized as follows: in Section 2, we report on the observational study about the definition and use of CP from the doctors' perspectives. This study gave us motives to undertake a modelling endeavor towards the integration of CP process schema into the CR data schema (see Section 3). This integration is the "conditio sine qua non" to begin conceiving innovative functionalities by which to support practitioners with an augmented integrated CP-CR system (see Section 4). Section 5 then proposes some ways by which awareness information on data context and clinical activities can be conveyed and Section 6 concludes the paper outlining the main next work in our research line.

2. PATHWAYS AS DOCTORS SEE THEM

During our observational study at NICU, we noticed that practitioners often referred to CPs during the interviews and informal talks, and so we were led to draw out a number of considerations advocating for their use in everyday practice. The main outcomes of the study can be described by the vivid images that doctors used to tell us why the clinical pathways are increasingly used within their ward, even beyond the demands for better accountability and rationalization coming from the hospital management. In what follows, we then mention two sketches that emphasize the relevant aspects about the definition and use of clinical pathways in the ward at hand. The name for these sketches have been suggested by clinicians themselves, namely: *Social Paving* and *Coastal Medicine* with respect to the definition and the use of CPs in the daily clinical practice, respectively.

Social Paving: the name regards the fact that in the process of building a reference CP, physicians also consolidate the usual best practices they undergo in their ward, in a social and participative manner. As put by the head physician, the process of defining which activities should be encompassed in a clinical pathway is akin to "paving" the usual paths that patients with a certain problem have so far followed from admittance to the full recovery of their health problems. We observed that the definition of a CP for its local use is a social process involving practitioners of a specific hospital unit, either at ward or departmental level, and that the CP creation comes from a local and contingent combination of both a *bottom-up* and *top-down* approach. When committed to some CP definition, physicians meet several times so as to share and validate the local practices they are used to put at work when dealing with a well understood problem and to choose which could be defined the best practice to deal with this problem under homogenous conditions (the so called "inclusion criteria"). In these more or less formal meetings, as they discuss about their current practices, they also refer to the current and most updated scientific evidences, to the new techniques that members of the staff might have become proficient with and to the current technical and organizational context in which they work. The scientific development is considered by taking into account the new evidences that are reported in peer-reviewed publications and official guidelines²; the technical and organizational milieus are considered in terms of either new structures and roles to involve in clinical activities or in terms of opportunities of gaining access to new diagnostic services and new equipments.

Accordingly, a CP is the result of a collaborative negotiation process where an acceptable compromise is reached between alternative ways to cope with a particular health problem locally, scientific evidences reported into official guidelines and technical and organizational constraints. As an example of the social nature of CP definition, the head physician proposed to focus on the CP they designed for the treatment of neonatal infections due to the beta hemolytic streptococcus group B, i.e., the so called GBS pathway. This CP was chosen since GBS is the leading cause of death in newborns and the NICU felt the need to address this problem in a more systematic and effective way. In regards to this

²Clinical practice guidelines are defined as "a collection of systematically developed statements to assist practitioner and patient decisions about healthcare for specific circumstances" [10].

CP, the NICU physicians had several talks about which was the best time interval to keep the newborn under observation to understand whether the first signs of GBS infection had to be manifest or not. Although each doctor proposed a slightly different time interval, at the end they agreed on a 48 hour time span. This was a compromise between significant spans reported in the GBS prophylaxis guidelines and what was considered a pertinent span by doctors in their local and actual experience. This anecdote sheds some light also on the fact that CPs can play the role of knowledge artifacts [2], i.e., of artifacts that stratify collective experiences into agreed best practices to make them available to single actors in their coping with patients with similar concerns.

Coastal Medicine: the expression comes after that the NICU head-physician told us suggestively that “guidelines are like gorgeous and huge transatlantic liners that can not enter the small harbors of our medical everyday practice, and CPs are like tugboats that are to bring such liners into a dock”. This lively image hints that the NICU CPs were also, and primarily, intended to support doctors *at the point of care* while guidelines were rather deemed as long and narrative collections of statement and recommendations that would be difficult to consult where there is a need for a concise reference. Doctors told us that they consult CPs to be reminded of *what* are the risk factors of a given intervention and of *when* to trigger the related alerting conditions, as well as to be supported in interpreting diagnostic results with respect to the overall illness trajectory and in making sense of patients’ reactions with respect to the overall therapy progress. CPs are then conceived of as supportive tools for the so called “coastal medicine”, i.e., a medical knowledge that must sail within sight of the coast — i.e., the very patient reaction — and that needs to be expressed as leanly as possible so as to cope with “shallow waters and surfacing reefs” (i.e., exceptions and contingencies that can not be encompassed in any manual or handbook). As an example of this, the head physician reported us that physicians dealing with the risk of GBS infection usually have to find a tradeoff between proper caution and prudent initiative. On the one hand, they would tend to anticipate the prescription of antibiotic therapy at the first signs of sepsis in order to prevent the full onset of the infection. On the other hand, administering antibiotics to an underweight infant can be more dangerous than having the infection progresses some further days. In order to balance these contrasting perspectives, physicians apply to the specific case their experience, ability to interpret the smallest signs, and sensitiveness. Nevertheless, GBS guidelines recommend a wide battery of tests in different circumstances before undergoing antibiotic treatment to facilitate the diagnosis of infection. In this specific situations, CPs are used by doctors to be reminded about which tests from those recommended by the guidelines have been chosen as the most relevant and feasible in their organizational context and about how to interpret their results to avoid, whenever reasonable, a premature prescription of antibiotic therapy.

2.1 Motives for integration

A number of CPs are used at NICU for a daily reference. These CPs are all denoted with respect to the problem or diagnosis they address, e.g., the GBS CP. CPs at NICU are usually represented as two or three page documents with sections mainly describing the a) inclusion criteria – i.e.,

under which conditions a patient is eligible for the application of a given CP – and b) the sequence of clinical activities physicians have to consider in order to deal with the specific problem; these activities concern the prescription of therapies, diagnostic examinations and other care interventions as well as the main decision points that are related to specific situations (e.g., what to do next if the result of a test is either positive or negative). This procedural knowledge is succinctly described in a diagrammatic form as flowcharts, in which activities are represented as boxes, decision and branching points as diamonds and causal relations as oriented arcs between boxes and diamonds.

The usefulness of relying on a graphical and succinct representation of the procedural knowledge referred by CPs during the daily practice was confirmed in several observational sessions: e.g., we saw doctors keeping in their pockets an informal print of the CP that was currently applied to a couple of their critical inpatients, and we observed a number of clinical records having a CP flowchart print as their first, though informal, front page within the main folder. Apart from the very way CPs are represented at NICU and on which medium, our attention was drawn on the fact that it was up to physicians to find proper ways to be supported by existing CPs *during* a situated practice and not only *about* a practice out of context. In our observations of daily practices of CP consultation, we compared actual practices and accounts from the specialist literature on paper affordances and functionalities (e.g., [11, 12]) and acknowledged the importance that these informal and flexible artifacts were paper-based: in fact CP prints were often used for informal and provisional annotating and their portability at the point of care was a clear advantage that was often mentioned during the interviews. However in these talks, practitioners also pointed out the shortcomings that could be traced back to the fact that CPs were *just* paper-based: the main one was that CP were sort of “dead letter”, that is not really connected with the data reported into the clinical record as well as with the very contingent and contextual facts occurring in the clinical case at hand. This necessary and continuous connection between process schemas and actual data reported into the CR was observed as an additional burden for physicians in the accomplishment of their daily work.

The possibility to recognize correlations between data and process schema has been seen as the preliminary step to make CP integrated with the clinical record and this integration as a way to make CP both *context-aware* and *proactive* in terms of functionalities supportive for practitioners. In our talks, practitioners showed that they would be glad to rely on a digitally-augmented CP-CR dyad that could combine documental content (i.e. data) and activities in order to: **(a)** Provide practitioners with the relevant clinical information stored throughout the CR with respect to the current activity in the CP; this support was advocated especially for sake of an effective information retrieval and exploitation that require an apt conciseness. **(b)** Give them awareness on which is the current task under completion and which events have brought to its corresponding data set; this support was advocated especially with respect to handovers when the evolution of the illness trajectory is as relevant as the punctual information [4]. **(c)** Give them access to the explicit and situated procedural context of data use and production; this support was advocated for

the constant need of practitioners to make sense of CPs on the basis of what is reported in the CR, as well as in different sources, like typically the Hospital Information System (HIS), as we will illustrate later on. **(d)** Help them in either avoiding or handling collaboration conflicts [16], e.g., by, respectively, making them aware of producer/consumer interdependencies on-the-go and by coordinating access to shared resources. These considerations were the main motivating rationales that drove us towards the integration of data and clinical activities, as these are considered in CPs. The approach underpinning this integration is outlined in the next section.

3. PATHWAY INTEGRATION INTO DOCUMENTAL ACTIVITIES

The starting point for integrating clinical data and clinical process maps is to identify which are the main interdependencies existing between record's and pathway's elements, so that the needed information to characterize these relationships can be properly modeled.

The interviews with the head physician of the NICU pointed out that physicians conceive of relationships between documents and sections of the clinical record and the activities reported into pathways in terms of either “what enters” into an activity (i.e., it is an *input* for an activity reading a CR document) or “what exits” from an activity (i.e., it is an *output* of an activity writing onto the CR). This led us to conceive *input* and *output* relationships occurring at different levels of document and process schemas since physicians could relate activities to even single fields of a specific CR form as well as to an entire multipage document stored therein. In addition to input/output relationships with documental entries, an activity can be characterized also by sets of conditions that either must hold true for it to begin or that are true every time it is accomplished. These conditions hold upon the clinical context that is made explicit and represented into the clinical record itself, in terms of clinical data (e.g., vital parameters, particular annotations) as well as upon other aspects of ward work that, at the NICU, were traced by or derivable from the HIS data structures: e.g., specific intervals of time elapsed during the accomplishment of an activity, notifications of exam completion, monitoring data from either biomedical or hospital equipments. Conditions that trigger, or better yet, enable a pathway activity, are called *preconditions* of that activity. For instance, the existence (i.e., arrival from the testing facility) of a test report triggers a new clinical assessment. Similarly, conditions holding upon relevant aspects of the “state of the world” that occur *because of* an activity are called the *post-condition* (or effects) of the activity. For instance, the effect of a X-ray examination is the tangible radiograph that doctors can handle after its completion; whereas the X-ray report is the *output* of the activity in the proper sense of the word; also the drowsiness of a patient coming back to the ward sedated from an invasive examination is an important post-condition to consider, since an activity having this kind of effect on the patient cannot be followed by any activity that would require an active role by the patient, like just serving the daily lunch. The approach of deliberately focusing on Inputs, Outputs, Pre-conditions and Effects (namely, the IOPE approach) to characterize the interdependencies between activities and either informational or tangible resources is certainly not new.

In fact, the IOPE conceptualization dates from the very first works in computing semantics (e.g., [14]) and it has been recently adopted in the definition of modelling languages and related standards for the Semantic Web (cf. e.g., [6]), as well as for the definition of Coordination Mechanisms [19] within the CSCW field. We also adopted it in a design-oriented framework, called *****, which we developed for the provision of awareness information in computer-augmented documental domains [?]. We then adapted it to the clinical domain mainly for the simplicity of its main concepts and because NICU practitioners seemed to favor our work of modeling and rephrasing what indicated into their CPs in terms of ‘reading’, ‘writing’ and ‘contextual conditions’.

After a thorough analysis of the main CPs used at NICU, we adopted a sort of four-step approach by which to integrate CR data and CP activities with the participatory assistance of the practitioners involved: **(i)** for each single activity referenced by a CP, detecting all those document-based sub-activities that can be traced back to the execution and proper documenting of that clinical activity (e.g., reading a report, writing into a form, sharing data with colleagues and gain access to particular artifacts); **(ii)** characterizing the document-based activities in terms of relationships with the documental context, i.e., detecting *input* and *output* relationships at the proper level of data granularity, ranging from single fields to entire sections and sheets of the CR; these heterogeneous documental items can be seen as nodes of a rooted tree, representing the CR and its compounding elements (i.e., sheets, sections, tables, single rows, single fields) as shown schematically in Figure 1. **(iii)** distinguishing³ between decisional points that can be considered akin to complex medical assessments – and hence requiring physicians’ direct involvement - and points where the pathway branches off to strictly alternative paths according to some *guard condition*. A guard condition is but a true/false conditional expression that is evaluated according to few and well specified clinical values; **(iv)** characterizing the main clinical activities, the assessment decision points and the activity ordering in terms of *preconditions* and *post-conditions* that hold on specific data values, events and other contextual elements that are deemed relevant to be represented into the computational system.

Although this stepwise approach could seem quite complex, it is just the literal and *afterward* translation of what we actually did quite unawares during our modeling sessions with some of the NICU representatives. The main effort required to clinicians in this integration process is then related to the identification and characterization in IOPE terms of the interdependencies between the clinical activities mentioned in their CPs of interest and the documents from the CR that are used in these activities. Yet, clinicians perceived the modeling effort as acceptable for a number of reasons: first of all, the approach is based on the externalization of procedural aspects they are already familiar with and of documental practices they accomplish everyday. Moreover, the effort is relatively limited in size: in fact, within a single ward, not every recurrent or common health problem is associated to a pathway and the number of use-intensive CPs by a certain staff is usually between ten and twenty, approximately the same magnitude as the

³In Section 2 we saw that decisional and branching points within a CP are graphically represented as diamonds and are then different from activities that are rendered as boxes.

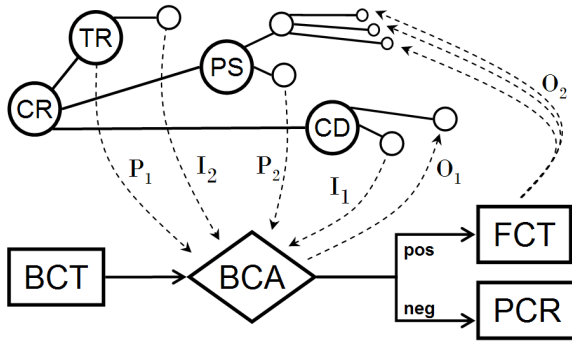


Figure 1: An excerpt from the GBS clinical pathway and its IOPE correlations with a subset of the CR data structure.

number of activities encompassed in a typical CP. Also as regards documents, although the official CR contains about twenty sections different in length and scope, only few of them are used extensively: e.g., the *prescription sheets* – i.e. those forms where all medical prescriptions, either drug and exams, are ordered – and the *clinical diary*, i.e. the notes where physicians document all their decisions and assessments during the management of a clinical case. Moreover, the *** framework that we employed for the CR-CP integration modeling relieves designers and user representatives from merely syntactic or notational peculiarities by providing them with a frame-like notation. The flexibility of ***, moreover, which is mainly due to the declarative paradigm it adopts, is aimed at facilitating a modular and iterative approach to the definition of data-activity correlations and at the incremental tuning of context-aware mechanisms that are based on these correlations [?].

In our participatory sessions, we noticed that several process maps resulted quite inhomogeneous in regards to the necessary and sufficient granularity of the information characterizing clinical activities. Some CPs were quite detailed in some sections, in terms of both preconditions and I/O correlations, and quite coarse in others. Yet, this was not perceived as a problem, but rather it suggested us that clinicians felt the need to describe and characterize at a finer-granularity only those indications they entrusted and relied more on. This latter point led to the concept of *criticality*, which means giving CP indications a weight that represents their locally-perceived importance and reliability as will be treated in more details in Section 5.

To give an example of CP-CR integration, let us focus on the medical assessment based on the “blood culture test” included in the GBS pathway (see BCA diamond in Fig. 1). In this complex decision activity, doctors are supposed to assess the result of a test (see BCT activity in Fig. 1) aimed at helping them evaluating the presence of GBS in newborn’s blood: if evidences of GBS bacteria are detected, a full-cycle therapy of antibiotics is prescribed (see FCT box in Fig. 1); otherwise, doctors accomplish a PCR test⁴ for further investigation (see PCR box in Fig. 1). When asked, physicians were able to strongly circumscribe the set of documents that are either read or written during this assessment activity: as its input, practitioners need to have access to those sections

⁴The Polymerase Chain Reaction, or PCR, is a test used to evaluate possible GBS infection.

of the *clinical diary* (I_1 in Fig. 1) that address the problem so as to decide whether it is the case to prescribe a complete cycle of antibiotics or not. In addition, physicians need also to consult the *test report* (TR) where the results of the blood culture test are officially reported by the examining facility (I_2). This report is always attached to the clinical record as soon as it is available from the laboratory. On the other hand, as its outputs, the assessment produces a new entry into the clinical diary (O_1), by which physicians exchange their remarks with the colleagues of the next workshifts. For what concerns preconditions, different events are considered for the activity to start: e.g., that the needed blood samples have been taken, that the usually time needed for the culture to become significant is elapsed (i.e., two days), that the official medical report has become available (see P_1 arc in Fig. 1, holding on the existence of the report); and that the child has been administered a first antibiotic therapy (see P_2 arc in Fig. 1, holding on a value of the Prescription Sheet). These are all events that are reported in some point of either the official CR or the HIS at their occurrence. For instance, blood taking is reported in the HIS as soon as nurses print and attach specific labels to blood tubes via the HIS-mediated booking service. As effects, the activity enables the PCR prescription (PCR) if the blood culture test is assessed to be negative. Conversely, if the test is considered positive, the assessment enables the activity in which a complete antibiotic therapy cycle is prescribed and administered (FCT). This activity writes on the *prescription sheet* (O_2 into PS in Fig. 1): more precisely, the PS fields where antibiotic administrations are requested, prescription date and time are registered, and the abbreviations of the prescribing physician are annotated. As said before, the number and type of inputs/outputs referenced by an activity in the integration model depends on the level of granularity that is most suitable with respect to the requested functionalities.

We undertook the systematic modeling of a few CPs that physicians deemed as sufficient for an initial test-bed for the integration of CPs and CRs. For our prototypical application, we adopted a *semi-automatic* evaluation of preconditions to keep aligned the current activity with the data stored in the CR. From the modeling point of view, we used the notion of pre- and post-condition to represent the procedural knowledge reported into the NICU CPs in terms of *flow relation* occurring between CP activities, i.e., what in the NICU flowcharts was indicated with small oriented arcs to express either temporal or causal precedences. In the GBS pathway for instance (see Figure 1) an assessment of the blood culture test (BCT) follows the prescription and execution of the test (BCT) and leads to either a full cycle therapy (FCT) or a PCR test. The flow relation expressing *execution order* is modeled in terms of preconditions and effects and the correct order of activity execution is ensured by the fact that one precondition of the following activity (in our example, the blood culture assessment) considers the internal state of the previous activity (the blood culture test execution), and hence it is true if and only if the latter activity has been fully completed. An activity is considered enabled only once all its preconditions are made true by the current context. Instead, guard conditions for simpler branching points are instead represented in terms of pairs of opposite preconditions inherited by the activities following the point: for instance, if A and B are two alternative activities following a branching point on body temperature (say,

either regular or high), A will have a precondition on regular temperature and B a precondition on high temperature. From the computational point of view, conditions are set to true automatically, according to the data clinicians add into the clinical record, whenever this updating is reasonable and feasible, e.g., for conditions holding simply on data existence and values. Obviously, this is not always the case: e.g., the updating regarding whether an activity is currently *in execution*, or *accomplished* was preferred to be left to the voluntary initiative of clinicians. In fact, automatically detecting whether certain activities are fully “accomplished” or still “in execution” is not always a trivial task⁵, and could lead to unsolicited and overloading information. On the other hand, some clinicians professed to be willing to notify the system activity states for two reasons: they appreciated the functionality of being reminded on current CP activities, especially in case when they are often interrupted. Moreover, they deemed the additional effort implied in manual notification to be definitely manageable for the magnitude of the task, as said above.

4. INTEGRATION-ENABLED FUNCTIONALITIES

Once the modeling activity had resulted feasible, we concentrated on the design of functionalities specifically oriented in making clinical pathways more integrated with the twofold process of supplying and documenting care. It was at that stage that we had to confront our ideas on process maps inclusion into situated practice with those of the intended users, especially the head physician. His high motivation on computer-based support to clinical practice was an invaluable element in guaranteeing us all the support and collaboration we needed to analyze the CPs used at NICU and collecting clinicians’ actual needs on CP inclusion in their work practices. Nevertheless, his enthusiasm about the premises of ICT of making CPs a more proactive and “constraining” tool for the sake of accountability, quality of care and clinical research led him to expectations for the prospective prototype that contrasted our research experience and gave rise to very lively discussions. We both agreed that CPs should never be intended as prescriptive tools, neither the head physician conceived of them as underlying algorithms for proper data reporting and proactive activity proposition. Yet, he stressed the CP value of artifact embedding “virtuous” knowledge on “what should be done, when and by who” (to use an expressions of his) and argued that its integration in the clinical record would be an irresistible occasion to make clinical practice more uniform, and hence outcomes more easily comparable so as to enable clinical meta-analysis, practice benchmarking and clinical research.

However, when we had to translate these generic concerns into specific functionalities, we had to share some key research questions like: To what extent, a CP has to be integrated in the regular flowing of documental activities? To what extent should a given and consolidated CP affect this flow, promoting efficient patterns of behavior associated to a particular category of health problems and conversely dis-

couraging ad-hoc, idiosyncratic and unexpected ways of coping with this problem when it occurs within a situated and unique clinical case? These questions were all about the role of recommendations in clinical work, the prescriptive nature that these indications can assume when they are based on the information gathered at the modeling phase and the role of tools that can enact these indications in providing support to everyday coordination and practice.

4.1 How to manage prescriptiveness?

In light of the discussions with the head physician, we undertook specific observational and interview sessions focused on the use of clinical guidelines and pathways at NICU. In these sessions, we observed that several prescriptive conventions did not derive from fully reconciled and agreed practices among clinicians, but were rather imposed by precise and strict laws prescribing how records ought to be compiled and which interventions should be accomplished to the patient when certain conditions hold true. We were told that trespassers of some of these laws would be prosecuted with the expulsion from the medical register and with other serious penalties that are also inflicted to whom fails to report any violation of law. To this regard, clinicians advocating the deployment of “constraining” and prescriptive technologies proposed to see them as preventive measures against legal problems and law infringements rather than a tight rein on their colleagues’ autonomy. Our role in the ongoing discussions was not to help assessing whether constraining functionalities could be either feasibly or usefully applied, but rather to disseminate in a highly receptive yet exigent milieu awareness on the actual drawbacks of workflow-like support in the hospital domain by making reference to a number of contributions from the CSCW field (e.g., [13,21]).

As result of our observations and discussions, we proposed to the head physician to conceive an electronic integrated CR as a tool that could flexibly convey and “enact” the intended prescriptiveness of process maps by switching between three different interaction modes, where the more constraining mode includes the functionalities and affordances of the less constraining one. These modes are α^1) *full action allowed with graphical hints*; α^2) *full action allowed yet with need for justification*; α^3) *partly bound action with reasons given*. The switching between these three modes would be done with respect to a number of aspects: e.g., according to regional or hospital policies, which are unlikely to change very often; or ward- and even single practitioner-specific presets (e.g., according to whether a clinician is a novice or an expert, an ICT enthusiast or skeptic); or, to the other extreme of variability, according to the current context and the very nature of the CP at hand. At the mildest level of prescription conveyance – the ‘modality’ α^1 – the system just hints what are the preferable or, conversely, heedless activities to do at any given time by changing the affordances and aspects of its graphical interface. The system leaves clinicians the freedom to undertake any action they deem necessary for the current moment. The same freedom of action is guaranteed at the second level – the α^2 modality – but in this case the system also requires the clinician to provide a written account of her decision into the CR to satisfy accountability concerns. At the strictest level of prescriptiveness – the α^3 modality – the system prevents practitioners from undertaking illegal activities – at least at documental and information system level – but also gives

⁵This because clinical activities are rarely sheer document-based tasks and usually involve events, actions and other situational aspects that usually are not formally represented or even specified at all.

them an explicit reason when it denies full access to a page or function for the sake of better accountability and transparency [9].

During a preliminary evaluation by a small and informal commission of clinicians, we were told that a system operating in the modality α^1 could play a role in the learning and community inclusion process of novices, while it would be important that proficient and expert users could turn off graphical hints and “go alone” whenever needed. The α^2 modality could be appreciated by expert practitioners with two stipulations: on the one hand, that they could postpone the provision of justification for the overriding of computer-based suggestions so as not to disrupt their work; and, on the other hand, that justifications could be expressed succinctly and in free format. Indeed, their point was that most of the times to justify unusual decisions means to justify but professional intuition and we all knew how difficultly intuition can be traced back to predefined categorizations [8]. In short, working in the α^2 modality was interpreted in light of accountability concerns – where the content of the justification provided matter for the sake of legal reconstruction; or from the point of view of proactive cognitive aid, where being prompted for justification contributes in making the current situation “present-at-hand” and in increasing practitioners’ consciousness of the effects of their action. The α^3 modality was agreed to be the most critical and the closest to the risks of straitjacketing use of workflow systems: accordingly, we agreed that it should be activated only in cases where infringements would result in serious coordinative breakdowns (e.g., when no data reported would imply impossibility to act any further) or illegal, senseless deeds from the medical point of view (e.g., prescribing drugs in lethal dose).

This complex negotiation of the kind of support to be provided by the integration oriented prototype led to a common view that practitioners with heterogeneous skills could use pathways as maps “flanking beside” the clinical practice and that could be supported by means of the affordances conveyed through the records where actual practice is documented. Consequently, we agreed that the approach employing awareness provision – and hence, the α^1 and α^2 interaction modes – would be the aptest for their coordinative needs, since it is the most feasible to smoothly convey the “scripting” nature of standard procedures and critical pathways in terms of *educational* recommendations to be evaluated within a broader framework in which ethical, legal, professional and human concerns sustain the autonomous judgement and conscience of care givers.

At this point we had to further investigate the aptest modalities by which awareness information can be conveyed to make explicit the possible differences between “the theory and the practice” as they occur in the medical domain. To this aim, we used the outcomes of a previous analysis [?] that led to the characterization of two main kinds of this information: awareness of the work context in the past – i.e., the working context when data were recorded – or of the current work context – i.e., the context where practitioners make decisions about either diagnostic or therapeutic next interventions.

4.2 Awareness provision on past and future work

In what follows, we illustrate these kinds of awareness in

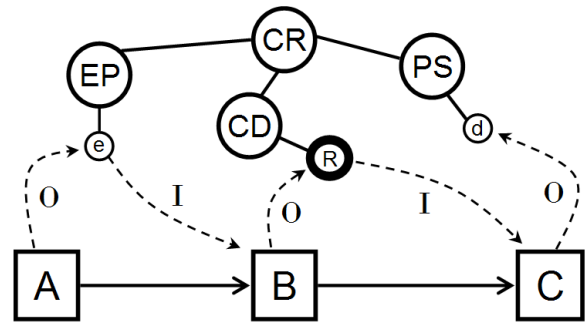


Figure 2: An example of accounting awareness on a remark R on the clinical diary (CD). Actors can be made aware of the activity producing R (i.e., the data reporting B), as well as of other relationships with other data and activities, such as exam and drug prescription (activity A and C in Figure, respectively).

relation to the integration of CPs and CRs.

Accounting awareness on past work context is conveyed according to logging information. The fact that clinical data and reference process schema are correlated allows the system to give awareness on i) who wrote or read⁶ a given remark (e.g., R in Fig. 2); ii) at which time, iii) which task activity was documented (activity B in Fig. 2), iv) and in response to which expectation and for which purpose (respectively, activity A and C in the CP example depicted in Fig. 2). Accounting awareness is aimed at making practitioners aware of past documental actions undertaken by colleagues: its provision can be either explicitly requested by the actor currently consulting the documentation (e.g., by accessing a sort of history or log of updates for a certain data field); or automatically provided by mechanisms that are triggered by contextual conditions, e.g., the fact practitioners are editing a field that is correlated with a datum inserted previously. This kind of awareness relates to the requirement to facilitate the “unpacking of the context” [3] of production of a certain documental value. The provision of this kind of awareness addresses the requirement (b) mentioned in Section 2.1.

Reminding awareness regards information that makes a user aware that she is supposed to do something, either about what she is currently working on or irrespective of it, to remind a particular actor or role that it is due time for the execution (or completion) of a previously scheduled task. For instance, blood samples at NICU are to be sent to laboratory within twelve hours after prescription. Only actors that consult the laboratory exam sheet during this time span can be reminded of an outstanding prescription; in addition to that, the system can warn any actor of the due task after the time limit has passed, no matter her current documental activity. The provision of this kind of awareness could address the requirement (a) mentioned in Section 2.1.

Coordinative awareness regards the information that the system can convey to make a user aware that her actions have an effect of others’ activities, i.e., that colleagues rely on her documental activity. Accordingly, coordinative awareness can be used to make actors aware of some activity in-

⁶provided that both operations require authentication

terdependency so as to prompt them to actively avoid or handle coordination problems. For instance, actors can be made aware that their activity precedes activities that are “waiting” until theirs has been accomplished. In so doing actors involved in the “blocking” activities could feel committed and determined in supporting the dependent colleagues so as to avoid resources underutilization or practitioners being kept idle and wasting their precious time. The provision of this kind of awareness could address the requirements (a) and (d) mentioned in Section 2.1.

Enabling and inhibiting awareness regard the information that makes actors aware of the preconditions (i.e., their existence, their importance, their current status with respect to the current context) of the activities they are going to accomplish. Enabling awareness is used to suggest which activities could be done since their preconditions are all true in the current context, i.e., the current content of the clinical record and some other contextual condition (such as absolute time or relative to some past event, relative position within the referenced CP, and the like). Awareness on what activity is enabled can be provided to convey a slightly milder indication on a to-do activity than reminding awareness. In fact, enabling awareness can be conveyed to point out that some task *could be* executed, rather than it *should be* executed. Obviously, in order to prevent information overload, only those activities that are very specific to a given situation are suggested to actors for commencement, i.e. activities that are fine-grainedly characterized in terms of preconditions during the modeling phase. The provision of this kind of awareness addresses the requirements (b), (c) and (d) mentioned in Section 2.1. Conversely, *inhibiting awareness* regards information about the activities that *should not be* undertaken, according to the current context, in view of the fact that at least one of their preconditions are false. The fact that the same patient is needed during different activities (e.g., two examinations) or that an activity necessarily needs another being completed (e.g., an examination needing the patient to be sedated) are all examples of what the coordination theory of Malone and Crowston [16] conceives of as *conflicting* activities, which can be avoided by timely conveying inhibiting awareness. As in the case of the enabling awareness, the designer has to avoid that unsolicited warnings are raised nagging actors about what they can not do at a given time. In order to prevent those cases to happen, such awareness information has to be delivered to actors only when they are actually providing the computational system with evidences that they are executing an inhibited activity.

5. AWARENESS PROVISION MODALITIES

When facing with the question of how the prototype should convey the above mentioned kinds of awareness, we also had to consider the way and extent a computationally augmented documental system is to support (or even propose) pertinent activities while discouraging (or even preventing) improper ones, in light of the peculiar requirements of the healthcare domain. Since this was the point on which physicians and our research team had the longest and most fruitful discussions, in what follows we concentrate on how the computational support can reconcile the “prescriptiveness” of clinical recommendations expressed by modelers at compile-time with the degree of autonomy needed when practitioners (as *doers*) confront them with a situated clinical case, i.e.,

at run-time.

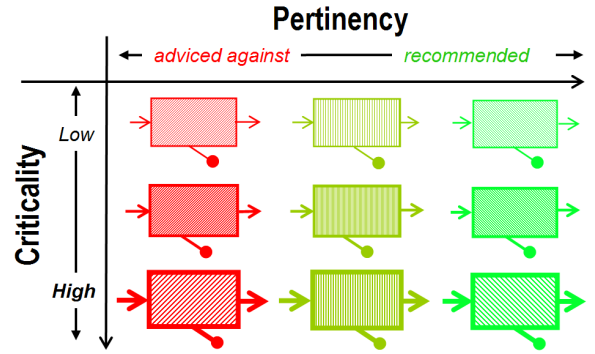


Figure 3: The pertinency/criticality conveyance in terms of intensity (line thickness) and colors (pattern orientation in greyscale rendering).

5.1 A bidimensional representation

A further analysis of the modeling outcomes and of the discussions we had about the extent prescriptiveness should be conveniently conveyed led us to identifying two complementary dimensions along which to compute enabling/inhibiting awareness. These two orthogonal dimensions are *criticality* and *pertinency*. As anticipated in Section 3, criticality indicates how important it is to strictly follow a CP for a doctor coping with the corresponding health problem. Pertinency relates to the extent the accomplishment of an activity is coherent with the current work context.

Criticality is associated both to activities and their preconditions, as part of the physicians’ effort of modeling the interdependencies among CR documents and CP activities. NICU physicians have indicated activities as critical for a number of reasons: e.g. activities that they should accomplish with as few interruptions as possible; which they would have to pay particular attention to; which require involved patients undertake painful treatments; which refer to either recommendations with strong evidence or to strict protocols of care. Critical preconditions are those preconditions whose validity is strictly necessary for the activity to be accomplished or even commenced. As said in Section 3, as regards preconditions expressing flow (precedence) relation, criticality means strictness of ordering. To give a didactic but clear example, the precondition stating that “slipping on shoes” can start only after that “slipping on socks” has been accomplished is deemed stronger, i.e., more *critical*, than a precondition requiring that “slipping on socks” precedes “slipping on a jacket”. Mutatis mutandis, CPs conveys *preferences* on the order by which clinical activities should be accomplished: in fact, by means of the criticality weight, doctors can express the extent they commit themselves in considering recommended orderings as strict indications in actual practice. Summing things up, when criticality involves activities and decision points, it refers to their role as milestones in the caring process (e.g., what cannot be skipped); when criticality involves preconditions of an activity, it refers to their relevance in deciding whether to execute the activity. Conversely, pertinency is conveyed by the system during the unfolding of the care process and regards the strength by which a specific CP activity is either suggested or advised against. The pertinency value is computed

taking into account the number and criticality of preconditions that are true with respect to all the preconditions of an activity: e.g., the pertinency of an activity whose preconditions are all true is higher than the pertinency of an activity having false at least one of its preconditions. Likewise, the pertinency of an activity whose most critical precondition is true is higher than the pertinency of an activity whose minor preconditions are true and its most critical false.

Criticality is conveyed through a corresponding modulation of *intensity* upon the graphical representation of the CP at hand (see vertical axis in Figure 3). Conversely, pertinency is conveyed by modulating the *color* of the elements depicted into the CP in use (see horizontal axis in Fig. 3). Since intensity regards the schema process, it is conveyed both when the CP is not yet in use and when it is applied to some clinical case, at run-time. Colors, instead, regard pertinency; therefore, they are set by the system to a CP in use only, i.e., at run-time. Intensity and coloring are orthogonal yet *combinable* operators. They can be both applied to all elements of a CP, according to both the schema process and the current context, respectively: i.e., flow relations, activities, decision points, and the IOPE correlations drawn in the integration model. The coloring makes arcs and elements colored with the corresponding color (either red or green, when activities are inhibited or enabled, respectively – see horizontal axis in Fig. 3). When intensity is applied to flow relations, the thickness of the corresponding arcs is changed accordingly. The same holds when intensity is applied to activities/decisions, when their borders are enlarged and colors (if any) made brighter.

To have a first feedback from NICU’s practitioners on how the intended functionalities concerning awareness on criticality and pertinency could work in practice, we mocked up an interface for the GBS pathway. A fragment of that CP is shown in Fig. 4 (an extension of Fig. 1) and will be commented in what follows.

5.2 Combining criticality and pertinency

In regards to criticality, the head physicians draw our attention on two contiguous sections of the GBS CP (see a and b sides in Fig. 4). In regards the side *a*, the GBS CP suggests that doctors prescribe a blood culture test (BCT box in Fig. 4) before administering any antibiotic (AT box) for the newborn suspected to be GBS infected. In fact, giving antibiotic to non-infected patients can be dangerous for the risk of creating drug-resistant bacteria and especially of endangering patients’ metabolism and, for this reason, doctors have to receive the informed consent from the newborn’s parents before prescribing the treatment. Accordingly, in order to remind doctors that the activity is risky and that the consent is really needed, the AT box is rendered as in Fig. 4 with a thicker border and it is connected to a critical precondition, respectively. Unfortunately, bacteria cultures need time to become significant for diagnosis (since bacteria need to grow and become manifest) and time is a critical dimension when health conditions of a weak premature infant are worsening and a child’s life is in threat. As mentioned in the ‘coastal medicine’ anecdote in Section 2, some NICU doctors tend to anticipate therapy prescription on the basis of other subjective indications and have it administered *before* a complete culture test is ready and sometimes even before it is actually prescribed, thus reversing the CP sequentiality. On the other hand, the GBS CP states that after two days from the

first bacterial sample and irrespective of the length of the therapy regime till then, a comprehensive assessment *must* be accomplished (BCA box in Fig. 4). In these two cases, the system reminds doctors about the different *criticality* of flow relations using different graphical clues: in fact, in situations where criticality is higher – e.g., where it is more strict the sequential order of accomplishment between the point in which antibacterial therapy is suspended after two days and the assessment of the culture to decide whether to complete the therapy or make a PCR test (respectively, the Full Cycle Therapy - FCT - and the PCR boxes in the Fig. 4) – the system displays a thick line connecting the corresponding elements of the CP. Conversely, in situations where the criticality level about sequential order is lower – e.g., in case of therapy administrations and diagnostic tests that can swap their execution order – the system displays a thin line connecting the CP elements.

The case depicted in side *b* of Fig. 4 gives us the opportunity to illustrate an interesting case of combination between *pertinency* and *criticality* conveyance towards greater cooperation between neonatologists of the same shift. In this case, doctors are supposed to prescribe a PCR test after the culture assessment, if this is negative. The availability of PCR results establishes a branching point where two alternative paths can be chosen according to the very test results. As PCR test outcome, the examining facility provides a report in which numeric values are used. The CP encompasses clinical knowledge by which values greater than two are clearly associated with a positive outcome, while values minor than one must be usually interpreted as a clear negative outcome of the test. The former case calls for a further battery of tests (activity E in Fig. 4), which are more expensive and also potentially more dangerous for the infant but can also detect GBS more clearly. The latter case means “exit from the GBS CP”, since no clear diagnosis of GBS could have been made that far and other hypotheses must be entertained (eventually with the support of other pathways). Since the probability of false negative results is much lower than the probability of false positive, doctors have modeled the lower branch in Fig. 4 as more critical than the upper one, so to say that if the test is lower than one there is strong evidence that GBS hypothesis can be rejected. A more difficult case occurs when the result value is between one and two, say 1.8 (see Fig. 4). In this situation, it is not straightforward for the doctor on-duty to assert test either positive or negative, although she can give the positive option a slight preference. In this specific case, the system identifies that at least a precondition of *both* the activities following the PCR decisional point are false. Accordingly, by displaying both the positive and negative branches in red, the system suggests that both positive and negative branches have the same pertinency and that neither of them should be undertaken, “rebus sic stantibus”. This is an all but trivial example of how the system can emphasize the pertinency of the activities encompassed as *routinary* within a CP and create them present-at-hand. In fact, since both alternative branches from the same condition are associated with the same pertinency and rendered with same color (red), the doctor is suddenly made aware that something out of the ordinary happened – i.e., that a routine test calls for further elements to consider. In addition, also criticality information is combined to give the doctor more information with respect to the corresponding GBS guidelines. The CP exit-

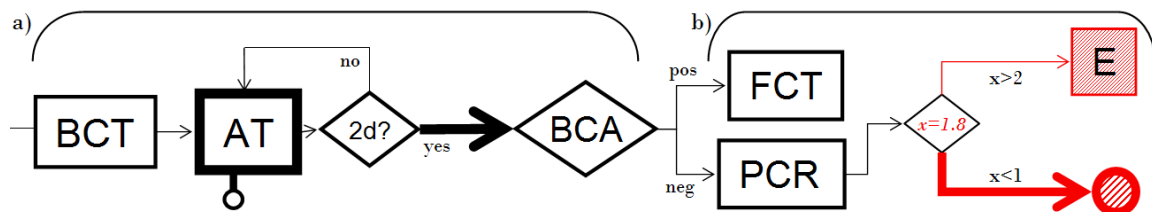


Figure 4: An exemplificatory excerpt from the GBS CP as the prototype would modulate its representation in terms of pertinency (color tone/pattern) and criticality (intensity, line thickness).

ing activity (the circle in Fig. 4) is rendered as more critical since, if the doctor chooses it, she is actually taking a far reaching decision that is going to affect the next course of clinical action since it is assumed that GBS infection can be excluded with some certainty. The enquiring activity (E in Fig. 4), instead, is rendered as less critical, since it just poses physicians in the position of searching other evidences in order either to confirm or exclude their hypothesis. Both indications clearly suggest the single doctor on-duty that the clinical case at hand needs further examination in relation to symptoms, diagnosis, and treatment that could be brought to her colleagues' attention in the next clinical meeting.

6. CONCLUSIONS AND FUTURE WORKS

In this paper, we presented an approach to integrate process maps – as Clinical Pathways in medical practice are – with the work context that is represented in terms of data reported in an official record system – as the Clinical Record in hospital domains is. In particular, we focused on the way an augmented record system can convey awareness information on the indications provided by process maps and task-oriented recommendations in terms of their intended prescriptiveness, local criticality and situated pertinency with the task at hand.

This approach resulted from the interactions we had with practitioners of a NICU; in particular, these interactions shed light both on the practical implications of the conflictual uses of these artifacts and on the difficulty to find an apt supportive technology for the situations at hand. This approach is coherent with the suggestion that systems that support “finding and presenting the planned “order of work” rather than enforcing it” [7] can significantly limit the risk of frustrating practitioners with the need to maintain both computer-based and traditional paper-based systems [13], getting bad results from both.

As anticipated, we are currently in the middle of our research path; next steps are the full implementation of the prototype and its evaluation with the NICU practitioners. Although the medical domain is very peculiar and critical, our preliminary analysis of the Archeology Research domain seems to share some basic features. For instance, the existence of intended protocols in the light of high contingency and harshness of contextual conditions, as well as of irreversibility of wrong behaviors during excavation. We then plan to more deeply compare the two domains with the aim of deriving synergies and evaluating the extent the approach is applicable to the new domain.

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