An ecological analysis of task subgoals during a simulated medical emergency

Thierry Morineau
CRPCC
Université Bretagne-Sud
Campus de Tohannic,
Vannes, France
thierry.morineau@univ-ubs.fr

Pascal Chapelain
Centre Simulation en Santé du Scorff, C3S
IFPS & Hôpital du Scorff
Lorient, France
p.chapelain@ch-bretagne-sud.fr

Philippe Quinio
Service de Réanimation
Hôpital du Scorff
Lorient, France
p.quinio@ch-bretagne-sud.fr

ABSTRACT
Whereas classical task analysis methods consider task goals and intermediary task subgoals as formal nodes in graph formalism, cognitive work analysis has brought a new dimension by considering task goals as ascribed in the concrete work domain. Complementary to this latter approach, we suggest analysing task subgoals as the satisfaction of constraints coming from equipment and work space management. We present a classification of deficiencies in task environment constraint satisfaction based on observations in a simulated medical emergency setting.

Author Keywords
Task analysis, medical emergency, constraint satisfaction, ecological approach

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Human Factors

INTRODUCTION

Classically, task analysis methods are based on graph formalism composed of nodes and links. Nodes represent initial, intermediary and final states and links represent sensorimotor or cognitive operations needed to produce states transitions during task performing. Whereas the final state corresponds to the task goal, intermediary states often correspond to sequentially ordered subgoals. Such a modelling was founded on the general problem solving model originally proposed by Newell and Simon, where problem-solving was represented as navigation in a problem-space through states and operations [1]. Well-known task analysis methods, like GOMS [2] or HTA [3], are based on this formalism.

Contrasting with this syntactic task approach, cognitive work analysis has brought a new dimension to task analysis by pointing out that task goals are not only abstract final states, but rely on concrete work domain properties that must be transformed through task achievement [4-6]. Through work domain analysis (WDA), properties on which tasks are performed can be described as a set of ecological constraints and degrees of freedom delineating a work space for an agent's actions [7]. Particularly, abstraction hierarchy as a methodological tool for WDA allows for classifying work domain properties according to different levels of abstraction from concrete (physical forms) to abstract properties (functions, processes, principles, purposes). By linking final task goals to concrete work domain properties, cognitive work analysis provides an ecological/situated work approach [4-6].

In this paper, we propose that task subgoals - as well as goals, can also be analysed as ascribed in the concrete work environment. Whereas goals refer to work domain constraints, a majority of subgoals refer to task environment constraints, i.e. constraints coming from the use of equipment and work space. By analysing task environment constraints and their satisfaction or not through different intermediary actions performed by an agent, we propose identifying different kinds of deficiencies that concern equipment and work space management. After a presentation of relevant previous works on intermediary actions involved in action schema, we will present a new classification of task deficiencies based on task environmental constraints that are more or less satisfied. This classification emerged from post-hoc observations of clinical practitioners (nursing assistants, nurses, medical interns) during an emergency scenario within a high-fidelity simulated clinical setting.

INTERMEDIARY ACTIONS IN AN ACTION SCHEMA

A major human ability resides in the capacity to arrange the world in order to get it affordable and easier to process cognitively [8, 9]. From this point of view, task environment can be considered as a set of constraints that must be primarily satisfied to allow the deployment of behaviour directly driven towards task goal satisfaction [10]. In the course of a given action, Greeno and his colleagues considered different intermediary states that can be qualitatively distinguished according to their functional meanings in an action schema [11, 12].

Three kinds of action schema components were pointed out (Figure 1). Prerequisites are conditions that must be true before a goal-oriented procedure can be performed. Preparing the task environment constitutes a prerequisite action.

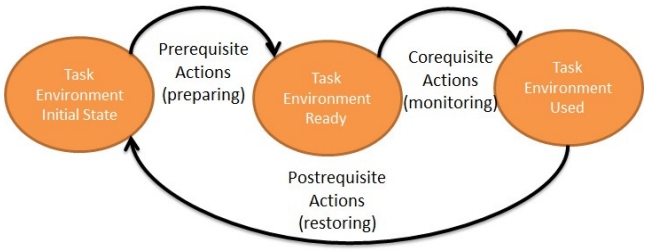

Figure 1. Action schema components interacting with task environment.

Corequisites are conditions to keep true throughout action performance. The satisfaction of a corequisite means to monitor the used equipment during actions and to respect work protocols. Finally, postrequisite actions satisfy postrequisite conditions that must be true upon completion of the action, after goal achievement. Postrequisite actions aim at restoring the task environment state. It allows the preservation of resources used through their storage and the retrieval of these resources for subsequent actions. Some studies on task analysis have incorporated some of these notions, like the MAD method which uses the notion of prerequisite [13]. It was also pointed out that action schema components would be stored in long term memory differently from goals. Whilst goals would be memorized as declarative knowledge easily accessible to consciousness, procedure and prerequisite and postrequisite actions would be stored as procedural knowledge [14, 12].

Within this framework, we propose identifying possible deficiencies in action schema components with regard to their capacity to satisfy task environment constraints. The following sections are devoted to the presentation of observations gathered during the simulation of a medical emergency situation within a high-fidelity simulator. Emergency situations involve a large number of care delivery actions within a short span of time. The loss of a few minutes during care delivery can be fatal for the patient. Additionally, a high-fidelity simulator provides facilities to record the caregivers' behaviour in a context close to a natural setting. Two sessions of simulated emergency situations have allowed us to classify task action deficiency according to how task environment constraints were managed by caregivers.

METHOD

Situation

The experience took place in a simulation room divided by a partition with a one-way mirror. This room contained a high-fidelity, realistic and interactive mannequin with verbal expression that was simulated with an audio/microphone system. Usual clinical parameters, like heart rate, blood pressure, oxygen saturation and breath were available. A multi-parameter monitor displayed these parameters. A set of classical medical equipment was also available in the bedroom. These simulation sessions were usual training sessions proposed to practitioners in the simulation centre of the Scorff Hospital (C3S). The original purpose of these sessions was to train professional caregivers in emergency work situations. The present study consisted of a post-hoc analysis of session events. The scenario was a "respiratory failure", where a difficult intubation occurred. Each session lasted 10 minutes. They occurred after a briefing stage during which the trainer presented the clinical context.

Participants

Six practitioners were observed. Two medical interns, three registered nurses (RN) and one nursing assistant (NA) were dispatched in two distinct sessions simulating the same "respiratory failure" scenario. Each participant was discovering the simulation setting for the first time. Session S01 involved 1 NA, 1 RN and another RN who came for assistance at 6'56'' (minutes, seconds). Session S02 involved 1 intern and 1 RN, and another intern who came for assistance at 2'20''.

Data analysis

The videos were watched and coded simultaneously by two coders: the trainer who participated in these sessions and a specialist in human factors research. Since it was an exploratory study, only data that can be clearly highlighted by the two coders as task management deficiencies in reference to the framework were collected. First, they were gathered according to the type of task management action, i.e. prerequisite, corequisite, and postrequisite actions. Afterwards, they were classified as the function of task constraint satisfaction and their topics (space or equipment management). The output findings were a task management deficiency classification illustrated by observed behaviour in simulation.

RESULTS

Task management actions

Task management requires a form of anticipation to ensure that environmental conditions are satisfied for the deployment of technical skills. Prerequisite actions implement this anticipatory activity through the management of the environment state. For instance, intern #2 verified whether the bag valve mask (BVM) was correctly attached during its use (S02; 1'40). In S01, the NA approached the emergency trolley (6'30). Beside these adapted actions to prepare the task environment, a set of deficiencies was also observed that we classified according to their level of constraint satisfaction.

Constraint relaxation: task management action partially or incorrectly performed

During observation, partially performed task management actions are difficult to distinguish from incorrectly performed task management actions. Indeed, a partially performed task management action can be considered an incorrect action. Both deficiencies involve constraint

relaxation that can produce deteriorated work conditions. This was the case when the caregiver incorrectly ventilated the patient from the bed side, because the bed had not been initially moved (S02; 1'40) leading to a suboptimal configuration of care delivery since the caregiver had to be positioned at the head of the bed. Constraint relaxation behaviour also occurred when intern#1 put the stethoscope on one of the hooks of an infusion pump stand, where the bag valve mask was already present. The other hook was occupied by an infusion tube (S02, 0'20). This situation would not facilitate reaching for the bag valve mask afterwards.

3'00: Decrease in oxygen saturation: no initiative in task management. The RN and NA answer to the patient's requests. *[Prerequisite/Unsatisfied constraint/Space & equipment]*
6'30: Bringing in the emergency trolley *[Prerequisite/Task management/Space]*
7'11: The AN uses the bag valve mask from the bed side *[Prerequisite/Constraint relaxation/Space]*
7'20: The NA does not monitor his ventilation action efficiency. He talks. *[Corequisite/Unsatisfied constraint/ Equipment]*

Table 1. Action schema components observed during session S01. In brackets and italics are the component characteristics

Propagation of task management deficiencies were also observed since the lack of postrequisite action influences the next prerequisite actions. In (S02; 10'50), the lack of postrequisite actions led to an accumulation of rubbish in the task environment. It provoked a congested work environment on the patient's bed, and consequently, additional constraints for the following actions.

Unsatisfied constraint: task management actions not performed

Sometimes, task management actions are fully absent even though evolution of the patient's state requires the anticipation of task management actions that would facilitate future care delivery procedures. The passivity of caregivers despite a change during a significant decrease in oxygen saturation represented such a situation (S01; 3'00). An absence of task monitoring was noticed when the nursing assistant did not carefully monitor his ventilation action efficiency while talking with his colleagues (S01; 7'20).

Additional constraint: additional task management actions

An unready task environment due to a lack of postrequisite actions can require significant involvement from the practitioners to arrange or restore it conveniently. The absence of postrequisite actions led to a congested task environment that produced additional prerequisite actions. For instance, intern #1 threw a dilatation catheter to the bed side because he failed to use it. Afterwards, intern #2 sought it (S02; 10'45). Similarly, intern #1 and #2 sought the syringe used to inflate the dilatation catheter in the environment congested with paper rubbish on the patient (S02; 10'50 & 11'05).

0'20: After using it, intern#1 puts the stethoscope on one of the hooks of an infusion pump stand, where the bag valve mask is still present. The other hook is occupied by an infusion tube. *[Postrequisite/constraint relaxation/equipment]*
0'36: Intern#1 must take off the stethoscope before taking the bag valve mask on the hook of the infusion pump stand. *[Prerequisite/additional constraint/space]*
52'': RN says: "Everything is tangled there". Detangling of the tubing. The intern helps the RN. *[Prerequisite/additional constraint/equipment]*
1'00: RN sets the instrument tray on the patient's legs and says: "The intubation tray. I put it on his legs. It's not great, but…." *[Prerequisite/constraint transgression/space]*
1'40: Intern#2 verifies whether the bag valve mask is correctly attached during its use. *[Corequisite/task management/equipment]*
1'40: Intern#1 inefficiently uses the bag valve mask on the right side of the patient's bed. *[Prerequisite/constraint relaxation/space]*
3'55: Intern#1 stops ventilation in order to arrange intubation. *[Postrequisite/constraint transgression/equipment]*
8'20: Intern#1 asks the nurse for the laryngeal mask airway, she gives him the dilatation catheter. *[Prerequisite/additional constraint/equipment]*
10'45: Intern#1 uses the dilatation catheter. After a failure, he throws the catheter to the bed side. Afterwards, Intern#2 looks for it. *[Pre-& postrequisite/additional constraint & relaxation/space]*
10'50: Intern#1 looks for the syringe to inflate the dilatation catheter. (Accumulation of paper rubbish on the patient) *[Pre- & postrequisite/additional constraint & relaxation & transgression/space]*
11'05: Intern#1: "Where is the catheter?" Intern#1 and #2 look for the catheter. *[Pre-&postrequisite/additional constraint & relaxation/space]*

Table 2. Action schema components observed during session S02. In brackets and italics are the component characteristics

We also observed additional task management actions, when the caregivers had to detangle the tubing (S01; 7'11

& S4; 52’’). Additional task monitoring actions can also be observed when intern #1 asked the nurse for the laryngeal mask airway and was then given the dilatation catheter (S02; 8’20).

Constraint transgression: transgressive actions of task management

Prerequisite and postrequisite actions arrange the task environment with the purpose of building an environment that is easy to use. Transgressive actions change that environment abruptly in order to reach a specific goal, without any preparation of the environment. It was the case when the nursing assistant set the instrument tray on the patient’s legs and said “The intubation tray. I put it on his legs. It’s not great, but…”(S02; 1’00). She did not respect the fact that it was a patient that would be uncomfortable with a tray on his legs. Similarly, the team accumulated paper rubbish on the patient without considering the effect that it would produce on an actual patient (S02; 10’50 & 11’05).

CONCLUSION

This study shows that whilst the notion of an action schema was also originally considered mainly as an abstract cognitive structure stored in long term memory (15), an ecological approach to action schema components allows us to highlight the fact that these components are implemented to satisfy concrete task environment constraints. Our classification of deficiencies in constraint satisfaction highlight that actions not directly oriented towards the task goal can significantly impact goal achievement. Whereas medical emergency situations intrinsically constitute risky situations for the patient, deficiencies in peripheral task environment oriented actions can indirectly lead to risky situations for the patient. In the future, further research will be needed to judge the cognitive status of such deficiencies. Indeed, task management behaviour that objectively appears deficient could cognitively represent trade-off strategies used by the caregiver to succeed in coping with multiple constraints, like when the nurse said that her action was not “great” [16]. We plan to analyse debriefing verbalisation contents to evaluate the cognitive status of task management behaviour that we observed in this study.

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