Shared Sensemaking and Clinical Decision-Making in Critical Care from a SA-oriented Dashboard

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ABSTRACT
At the start of the COVID-19 pandemic, Intensive Care Units (ICUs) admitted an unusually high number of patients suffering from the most severe respiratory effect of the disease. The clinicians worked in teams in a context where resources were limited, and efficient resource management was key to ensure on-time healthcare delivery. Our team of researchers adopted the situation awareness (SA) model to design a SA-oriented dashboard. The main research objective was to improve clinicians' situation awareness, through the visualization of resource management key indicators to perceive on what is going on, comprehend its meaning and project future actions. A total of 17 clinicians participated to the dashboard design. We used the conceptual framework of the staff-stuff-space-system-of-care (4S) factors to resource management in critical care. A user-centred design method allowed to define the dashboard key indicators from the clinicians' situation awareness goals (perceive, comprehend, project) and 4S information requirements. However, the outcomes revealed that little was known on how the 4S factors to the clinician situation awareness contributed to a shared sensemaking and to clinical decision-making among the team members. We found a core factor to a shared sensemaking identified as "health Status at bedside". This 5th "S" factor informs the clinician team on both the 4S (staff-stuff-space-system regulation) resources in used and the clinical condition at bedside. From then, we identified the 5S factors as the drivers of the clinicians' cognitive processes in critical care. We synthesized the research outcomes in the Situation Awareness and Shared Sensemaking Decision Model (SASS). We conclude by suggesting that much can be gained from the evaluation of the SASS model in critical care.

KEYWORDS Clinical Decision-making, Critical Care, Dashboard, Intensive Care Unit, Shared Sensemaking, Situation Awareness.

BACKGROUND

During the COVID-19 pandemic, in support of the clinicians working in the largest Canadian mother-child hospital located in Quebec, our research team designed the situation awareness-oriented (SA-oriented) dashboard (Boudreault, L. et al., 2022). We adopted the situation awareness model to study the human and ergonomic factors impacting the clinicians' cognitive processes to perceive, comprehend and project actions in complex and dynamic environments of critical care. The SA model (Endsley & Jones, 2004) is recognized as one of the most prominent models to study cognitively complex functions in demanding real-world situations (Roth E. et al., 2022).

A total of 17 clinicians participated to the SA-oriented dashboard design (Figure 1). We used the conceptual framework of the staff-stuff-space-system-of-care (4S) factors to resource management in critical care (Christian, MD & Kissoon, N., 2020). A user-centred design method

allowed to define the dashboard key indicators from a Goal Directed Tasks Analysis (GDTA). GDTA is a modified form of cognitive task analysis that has been utilized by proponents of SA theory for determining SA requirements in varied fields like aviation, army, railroad, nuclear, assistive technologies and computer science (Sharma et al., 2019). We applied the GDTA in the field of critical care, from the association of the clinicians' situation awareness cognitive goals (perceive, comprehend, project) with their clinical tasks and 4S resources requirements. This resulted in the display of 15 key indicators (KIs) at bedside and 6 KIs related to the overall unit in the central area. In the end, we expected the 21 KIs of the SA-oriented dashboard would improve the clinicians' SA and decision-making processes.

Figure 1 – SA-oriented dashboard prototype

However, we found that little is known on how the visualization of resource management KIs contributed to clinical decision making. Staff loading ratios (patient-to-nurse, patient-to-doctor) and list of incoming patients displayed in the central area favored the team's discussion on how many new patients could be admitted to the unit. This information was not readily available to clinicians on the previous dashboard and discussions on admission rate were more laborious for them to make sense of the unit status. Hence, this paper studies this gap in knowledge through a review of theoretical work on the cognitive processes of situation awareness, sensemaking, shared sensemaking and clinical decision-making. We propose a new model that synthesizes the major findings on the clinicians' cognitive drivers of clinical decision-making from three resource management levels: bedside, critical care organizations and the system-of-care.

The rest of the paper is organized as follows. First, we present related work on the 4S factors to resource management followed by studies on individual and team cognition. Second, we present the outcomes of our research on the design and usability of a SA-oriented dashboard. Third, we synthesize the findings in a new theorical model. We conclude with the research perspectives.

RELATED WORK

4S FACTORS TO RESOURCE MANAGEMENT IN CRITICAL CARE

Resource management in Intensive care unit (ICU) is often referred by the 3S factors of staff, stuff and space: teams need to know the medical staff on duty, their skills and competencies, the materials and medical supplies available or lacking, as well as the beds spaces available to treat patients (Fiest, K.M. & Krewulak, K.D., 2021). Whether the context of critical care is in ICU or in pediatric intensive care unit (PICU), the unit requires a standard of care to sustain the 24h/7days changes in the personnel (staff) providing critical care, the places where critical care may be delivered (space), and the supplies available for providing this care (stuff) (Christian, M.D. et al., 2011).

The capacity to deliver care and clinical decision were strengthened or limited by the strongest or weakest link powering the 3S resources management. This was obvious at the start of the COVID-19 pandemic, as there was a lack of ventilators (stuff) to treat patients, followed by shortage of clinicians (staff) for care delivery while they needed to isolate themselves after having caught the virus (Grasselli, G. et al., 2020)(Thompson, C.N. et al., 2020)(Vranas et al., 2021). Although the triage and treatments of patients in hospital-centric plans were previously based on the 3S factors, there was a clear need to prioritize the allocation of scarce medical resources from an integrated population-based, system-wide solution (Christian, MD & Kissoon, N., 2020). It emerged as the 4th S factors under the name of System of care regulation. Public health authorities in most of the countries in the world hold this mandate, reinforced collectively by their inner adaptation of guidelines and rulings at the institutional level by the world health organization (WHO, 2022). The WHO's recommendations on a new *modus operandi* emphasized the countries' requirements to put in force public health policies and ruling. Rules formulated at the system-of-care level (4th S) directly influenced the clinician's situation awareness and decision for resource allocation at bedside.

TEAM COGNITIVE PROCESSES

Situation awareness (SA) is one of the most influential model in human factors research to study cognitive processes impacting decision and performance (Stanton et al., 2017). SA is a state of knowledge attainable from three levels of non-sequential, ascending cognitive processes defined as "the perception of the elements in the environment within a volume of space and time, the understanding of their meaning, and the projection of their status in the future" (Endsley, M.R., 1988). Endsley's SA model was originally developed in the field of aviation to study the origins of human errors in aircraft accidents (Jones & Endsley, 1996) and has since made its way to other complex, dynamic settings to improve the operator's assessment and decision making in military operations (Riley, J.M. et al., 2006), marine navigation (Haffaci, K. et al., 2021) and medicine (Schuster & Nathan-Roberts, 2017).

However, the cognitive emphasis in the SA model is on the individual. In healthcare settings, even if one person is leading the decision to action, a prior step is sharing the knowledge and

expertise to make sense of a situation (Hoffmann, T. et al., 2014)(Abbasgholizadeh Rahimi et al., 2017). During the pandemic, when hospitals were asked by the system-of-care to postpone surgery to care the sudden increase of patients suffering from the worst effect of the COVID-19 respiratory disease, the clinicians had to share their understanding of the situation to decide on actions. Shared sensemaking, situated cognition and shared SA are required to study decision-making at teams' level. All three are recognized as critical input to decision-making, but they differ in their research approach and methods

Sensemaking is defined as the ability or attempt to make sense of an ambiguous situation; it is the process of creating situational awareness and understanding in situations of high complexity or uncertainty in order to make decisions, often in response to surprise (Klein et al., 2006). Information is at the heart of the sensemaking process. Problems arise when information may be missing; in this case, the sensemaking process starts by making guesses using retrospective knowledge (Ntuen, C.A. et al., 2010). This is observed with experts when they use their more efficient rational "slower thinking system" and their more intuitive but risky "fastest thinking system" (Kahneman, D., 2003)(Kahneman, D., 2011). The theory of the fast and slow "thinking systems" is useful to explain how he visualization of real-time information on the SA-oriented dashboard could sustain a balanced shared sensemaking from a real-time learning process during a chaotic situation created by an unusual flow of patients as during the first waves of the COVID-19 crisis. Moreover, if the SA-oriented dashboard information is not updated, and do not reflect the real situation, a shared sensemaking could contribute to correct the cognitive dissonance emerging from the fast and slow "thinking systems".

In organization theory, shared sensemaking among team members is considered a situated cognition process mostly studied in naturalistic context i.e., when and where the actions take place (Klein, G., 1993)(Orlikowski & Baroudi, 1991). When team members have a problem to solve, they share their perception and understanding of events and project a solution or solutions, allowing them to adapt to an evolving situation of deciding in action (Kaplan & Orlikowski, 2013). In organizational settings, where groups of individuals work, there exist cognitive mechanisms of memory recall of actions in similar circumstances, which also lead to imitation and acceptance behaviors to cope with solutions proposed by others (DiMaggio & Powell, 1983). Then, a mutual learning of the members of a team influence the individuals SA. The construction of meaning is a dynamic process of shared sensemaking which is more than the sum of the individual SA of each team member. Then, we cannot ignore in the design of a SA-oriented dashboard, the cognitive phenomenon of shared sensemaking from the dynamic process of learning in action which eventually lead to deciding.

In systems and engineering research, team SA is defined as "the degree to which every team member possesses the SA needed for his or her job" (Endsley, M.R., 2021, p. 12). Within each teams, there is a need for shared SA (SSA) which is "the degree to which team members have the same SA on shared SA requirements" (Endsley, M.R., 2021, p. 12). In the SA theory, teamwork and shared sensemaking are considered an outcome of individual decisions aggregated to the level of a team, leading to a posteriori rather than a "real-time" measurement of the decision and performance of action. However, there is no explanation as to how the individual SA participates to the building of a shared sensemaking among team members and why this influence decision-making.

In this work, we studied how the 4S resource management factors contributed to the building of a shared sensemaking among team members in "real-time" situations in critical care. This understanding will be helpful to improve the cognitive processes of the clinicians in the design of an “intelligent” SSA-oriented dashboard. To this end, we proposed a new model on Situation Awareness and Shared Sensemaking (SASS) that synthesizes this knowledge.

METHODOLOGY

We conducted a goal directed task analysis (GDTA) with 17 ICU clinicians working in ICU to identify their SA requirements (perception, comprehension, projection) according to their everyday goals, activities and tasks. To trigger clinician’s SA and decision making, we used as a probe a SA-oriented dashboard (Hébert-Lavoie, M. et al., 2021) under scenarios of increasing patients’ load. We transcribed the interviews and analyzed the verbal protocols, categorizing the clinicians' SA requirements (perception, comprehension, projection) under the resource management 4S factors.

RESULTS

We found three evidence that clinicians perceive and comprehend the information presented on the SA-oriented dashboard according to their priorities (Tan K.W. et al., 2019).

First, we found the clinicians SA was driven by the 4S factors informing the clinician team on the management of resources in the PICU. What was determinant to them were the displayed of both information, 4S resources at bedside, and the clinical condition at bedside. This revealed a 5th S factor – health Status at bedside – informing the clinician on the clinical condition of patients was pivotal to a shared sensemaking. When the clinicians were asked if they could admit new patients, the clinicians first built their sensemaking of the overall health condition of the patients from 5S indicators displayed at bedside: the number of nurses at bedside (staff), equipment and material (stuff), bed localization (space), COVID status (system-of-care) and nurse workload and clinical condition at bedside identified as the “health Status at bedside”.

Second, the visualization of the SA-oriented dashboard speeded up a shared sensemaking on the overall admission capacity. We found the display of the 32 beds’ occupancy was not the dominant factor of the decision to admit. It was the staffing of nurses at bedside and the patient-to-nurse ratio that were the two most influential factors to decide how many patients were admissible (Wynendaele et al., 2019). These two S factors (staff, health Status at bedside) reduced the mean time to clinical decision to admit, wait to admit or transfer in other PICUs since it took less than 30 seconds to make sense of the situation with the SA-oriented dashboard and between 30 and 60 seconds from the dashboard in used before the pandemic.

Third, the PICU status indicator – open to admission (green), selective (yellow), very selective (red) – contributed to the clinicians’ perception on the capacity to admit. However, before deciding to admit, they looked at the overall situation to make sense from a comparative assessment between their comprehension of the 5S indicators displayed on the SA-oriented dashboard. It revealed that the SA indicators were also participating to a shared sensemaking, since similarities of their cognitive processes were influential to clinical decision-making.

The SA-oriented dashboard usability limitations to the understanding of the impact of a shared sensemaking on clinical decision-making were the following: the interviews were conducted

remotely, on an individual basis due to the COVID-19 confinement measures, the PICU status indicator to decide on admission was refreshed manually instead of being automatically evaluated in real-time situation, and the display of the 32 beds arrangements in the PICU was static, limiting its use in other critical care hospitals.

DISCUSSION

The results presented above put in evidence two major information requirements of a SA-oriented dashboard. The clinicians use and integrate the information provided by the SA-dashboards when they reached some sort of common goals on resource management and clinical condition of the patient before deciding on action. We found the visualization of the SA-oriented dashboard helped the clinicians to cope with an uncertain future regarding clinical decision-making. Specifically, under conditions of ambiguity and competing interpretations, without some shared understanding of the future, plans or decisions are hazardous (Kaplan & Orlikowski, 2013).

We found 5S factors being influential to a shared sensemaking on what is going on. This is coherent with the fact that in acute care settings when the problems are ill structured, that time is urgent rather than ample and the environment is dynamic and uncertain, the stakes are high to share information and create a common ground of understanding to come out with shared decisions (Klein, G. et al., 2005). It is aligned with the evidence that a shared decision-making (SDM) is essential in healthcare settings (Abbasgholizadeh Rahimi et al., 2017).

We also found the key indicators displayed on the SA-oriented dashboard shaped a shared sensemaking from three levels of decision in critical care hospitals. An operational level at bedside, a tactical level in the critical care hospital and a strategic level through regulation by the system-of-care. This is coherent with the results from a literature review on the typology of dashboards in hospitals: strategic at the organizational level, tactical at the unit level (e.g., ICU), and operational at the individual level (patient/clinicians in ICU) (Buttigieg et al., 2017). It reinforces the point that in hospitals where the teams of clinicians work, clinical decision-making depends on a shared understanding of the operational, tactical and strategic decisions to action (Pace, A. & Buttigieg, S.C., 2017).

Our study on resource management in critical care hospitals added new knowledge to the work on dashboards for public organizations (Kaplan, R.S. & Norton, D.P., 1992) (Kaplan, R.S., 1996) (Kaplan, R.S. & Norton, D.P., 2001a)(Kaplan, R.S. & Norton, D.P., 2001b). In a system-of-care, hospitals' managers and clinicians have a role of accountability to society, which is present in the research findings. We contributed to new knowledge on the capacity of a SA-oriented dashboard to improve clinical decisions from the integration of the information requirements present in three system-of-care levels: regulation at the strategic level, resource management at the tactical level and bedside health status at the operational level. These three levels contributed to an individual situation awareness and sensemaking, which in turn participated to a shared sensemaking of the clinicians before they decide on action.

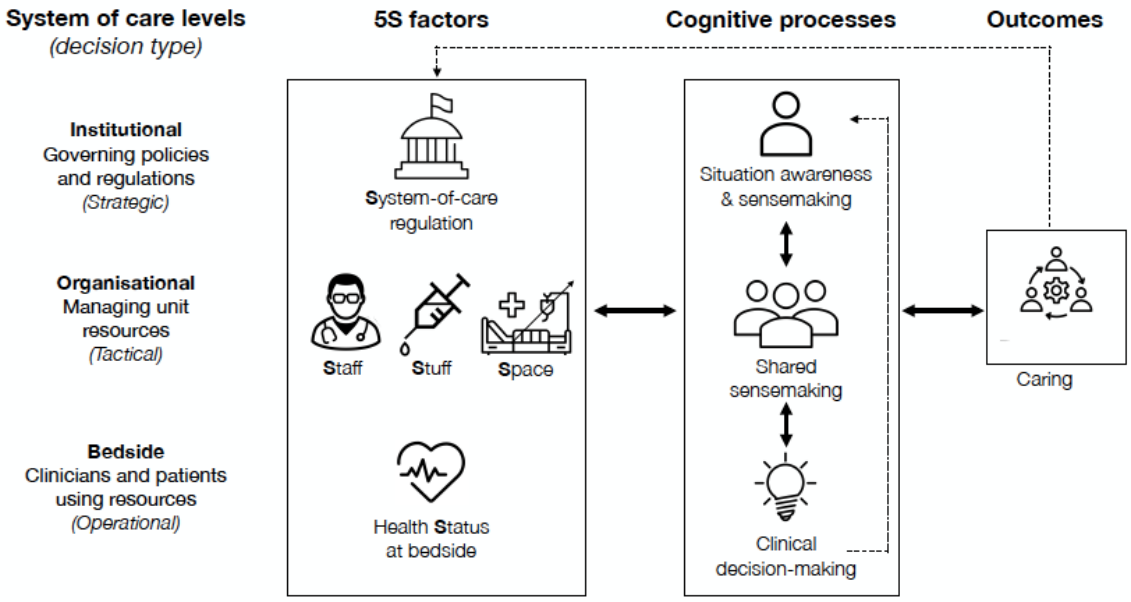

Figure 2–Situation Awareness and Shared Sensemaking Decision Model (SASS)

We synthesize our findings in a Situation Awareness and Shared Sensemaking model (SASS). The SASS model illustrated in Figure 2 presents the 5S factors "**S**ystem-of-care-**S**taff-**S**tuff-**S**pace-health **S**tatus at bedside) as an input to three cognitive processes: an individual's SA and sensemaking (perception, comprehend, project) and at the team level a shared sensemaking and clinical decision-making. The ultimate decision may be taken by only one individual in the group of individuals, but the model emphasizes the way a team of clinicians comes out to a decision from a shared sensemaking cognitive process. The outcome of the cognitive processes is caring. It could be evaluated from its impact on the quality and safety of care. However, this aspect is beyond the scope of our study.

The SASS model conforms to the input-transformation-output and feedback loops present in sociotechnical theories (Langley, 1999)(Rogers, E.M., 1983) (Nutt, 1984) and engineering systems theories (Karsh et al., 2006). Sociotechnical theories are present in two dominant models on resources management in healthcare organization: the structure-process-outcome (SPO) model (Donabedian, A., 1966)(Donabedian, 1988) and the system-processes-outcome of the model of Systems Engineering Initiative for Patient Safety (SEIPS) (Carayon et al., 2006) and extended models SEIPS 2.0 (Holden, R.J. et al., 2013) and SEIPS 3.0 (Carayon et al., 2020). When compared to the SPO and SEIPS models, the SASS model presents a new understanding on how the cognitive process of a shared sensemaking among the clinicians contribute to the cognitive clinical decision-making process and the final decision on caring.

CONCLUSION

In this study, we explained the main drivers to a shared sensemaking for resource management and clinical decision in critical care. We identified the main factors as the 5S: health **S**tatus at bedside, **S**taff-**S**tuff-**S**pace in the ICU and the hospital and the rules and directives from the **S**ystem-of-care regulation. We showed that the 5S factors shaped three cognitive processes: an individual's SA, and two at the team level for shared sensemaking and clinical decision-making.

We synthesized these findings into the SASS model that explains the relationship between the 5S factors on resource management and clinical decision types from three levels of understanding: institutional, organizational, at bedside. The 5S factors are input to the five cognitive processes: SA, shared sensemaking, clinical decision-making, involved in the outcomes on caring.

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