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Supporting dynamic and distributed decision making in acute care environments: Insights from a cognitive ethnography

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Abstract

The way that medical decisions are carried out in hospital environments has undergone radical changes in recent years, in part as a result of the changing landscape of care. To make decisions, physicians are expected to keep abreast of a growing and changing body of medical and patient knowledge, collaborate more with clinical colleagues, and utilize more technologies to inform care than ever before. This dissertation reports on a five month cognitive ethnography in an ICU in Ontario Canada, and utilizes distributed cognition to understand the challenges that physicians face in making decision in modern acute care environments. It also seeks to elucidate the strategies used by ICU physicians to cope with the challenges associated with using information from social, material and technological sources in decision-making. My findings demonstrate how information resources are (1) Objectivist, in that too much attention is paid to supporting the formalized, outcome-centered aspects of medical thinking, without due regard to the processes involved in adapting decisions to their situation; (2) Fragmented, in that, while information resources are often well-designed when considered in isolation, they force physicians to bridge gaps in the logic of access or representation when working between resources; (3) Individualistic, in that information resources are often tailored to support the cognitive needs of individual physicians, leaving the cognitive needs associated with collaboration unsupported, and sometimes undermining them. To compensate for the challenges associated with using objectivist, fragmented and individualistic information resources, physicians employed a number techniques, including relying in paper and other flexible artifacts, interpersonal clinical communications, and engaging in mobility work. This research brings us a step closer to understanding how people, paper, and technologies function together to fulfill the complex and dynamic needs associated with making medical decisions.

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Chapter 1 Introduction

The Problem and Research Question

Medical expertise is among the most voluminous and intricate forms of professional knowledge one can acquire, taking years of study and training to master (Gawande, 2010). Medical expertise is funded through a vast body of medical knowledge and clinical experience, which physicians must apply adaptively in decision-making, balancing it in their clinical judgment and according to the dictates of the situation (Montgomery, 2005). In recent decades, the landscape on which physicians make decisions has changed dramatically. New demands on clinical practice (Hafferty & Light, 1995), a changing rate in the production of medical knowledge (Gawande, 2010), new expectations around collaboration and group practice (Boreham, 2004; Miller, Moore, Stead & Balser, 2010), and the interpenetration of information technologies into every aspect of medical decision-making (Berg, 2003; Wears & Berg, 2005) are the major signposts of the new terrain. The new landscape of medicine does more than merely change the periphery or backdrop against which decision-making is achieved. Rather, it alters the very nature of clinical thinking and decision-making, what physicians need to know, and how they learn (Stead, Searle, Fessler, Smith, & Shortliffe, 2011).

In the context of this new landscape is a growing awareness of a pressing need for a better understanding of the processes underlying medical decision-making and how to support them more effectively (Patel, Zhang, Yoskowitz, Green & Sayan, 2008). Decision-making, which may generally be thought of in terms of a process of moving from a current state to a desired state without knowing immediately or intuitively how to do so, requires practitioners to acquire and use information, and is sensitive to the environment in which it is carried out (Fidel, 2012). As the complexity of the landscape on which decisions are made increases, so too does the complexity of medical decision-making, and the complexity of adequately supporting them (Franklin et al., 2011; Wears, 2012). While generally true across the spectrum of healthcare, it is particularly true in

acute care settings, where decision-making is dynamic and changing, time-pressured, interprofessional, and commonly carried out under suboptimal conditions (Nemeth, Nunally, O'Connor, Klock & Cook, 2005).

Decision-Making and Decision Support in the Changing Landscape of Critical Care

In response to the rising complexity of medicine, the dominant approach to supporting decision-making lies in the development of standardized forms of information, sometimes embodied in paper resources, artifacts and technologies aimed at reducing uncertainty and standardizing care (Chaudhry et al., 2006; Timmermans & Kolker, 2004). Information technologies in particular have arguably been the main pillar of the decision-support strategy in hospital and critical care environments (Wears & Berg, 2005). The model of information systems and medical work that has been influential in North American healthcare, since at least 1992, has in general represented medical decision-making as an endeavor of technical rationality and scientific reductionism, codifying patient information as a series of discrete data points that represent the objective condition of a patient (Wears, 2012).

More than information technologies, decision support efforts take on the form of new structures of team work and other interdisciplinary arrangements (Lingard, 2012; Boreham, 2004), new types of information delivered at the point of care, or new expectations on workflow arrangements. Often these changes are overlaid on top of a traditional paper-based information infrastructure, one that is built around a model of the lone, autonomous physician, who holds ultimate authority on their[1] patients (Miller et al., 2010; Stead, Searle, Fessler, Smith & Shortliffe, 2011).

The effects that these interventions have on decision-making have often been a mixed bag of successes, failures, and host of unintended consequences (Ash, Berg & Coiera,

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[1] Across the text, I use the third person plural in lieu of the third person singular (his/her) to support a gender-inclusive reading.

2004; Campbell, Sittig, Ash, Guappone & Dykstra, 2006; Patel, Zhang, Yoskowitz, Green and Sayan, 2008). The failure to achieve consistent results in decision support interventions lies in the limitations that characterize the approach to decision making most commonly used, which fails to sufficiently account for the complexity and nuance of situated clinical thinking. The majority of decision-making research in medical contexts is conducted from the traditional or classical paradigm of cognition (Hazlehurst, Gorman & McMullen 2008). The traditional approach to medical decision-making obscures the influence of the environment, and tends towards a reductionist treatment of individual practitioners, information objects, and technologies as distinct and separate objects of study (Marchionini, 2008). Hence there is a lack of understanding about how practitioners use information resources in their environment to meet their complex and multifaceted decision-making needs, and how their thinking is shaped by those resources in turn. Many researchers have called for a new approach so that we can better understand how information provided through technology, people, and artifacts combine with one another as a whole system that shapes and serves medical decisions (Ash, Berg & Coiera, 2004; Gabbay & le May, 2010; Greenhalgh et al., 2009; Hazlehurst, Gorman & McMullen, 2008; Patel et al., 2009; Wears, 2012).

Thus, my overarching research question is:

> *How does the system consisting of technologies, practitioners, and artifacts work together to provide the information needed to support medical decision-making?*

And further,

> *In the event that the system that provides information is not aligned with the needs of medical decision-making, how do clinicians cope or compensate for the misalignments?*

In the remainder of this chapter, I will discuss the theoretical and methodological approach of this thesis, which will serve as the foundation for highlighting the key contributions that this thesis seeks to make to existing theory and practice. After this, I will encapsulate and summarize the dissertation outline.

Theoretical Foundation and Methodological Approach

In medicine, decisions usually rely on several individuals working together, with the aid of information artifacts, work routines, and a well-developed sense of professional background knowledge. Because of this, understanding how medical decisions are made involves expanding the unit of analysis beyond what is traditionally considered 'cognitive' to the activity system – that is, all the information resources (e.g., people, tools, artifacts, understandings, routines) that have a bearing on medical decisions (Clark, 2008; Hazlehurst, Gorman & McMullen, 2008; Hutchins, 1995; Kirsh, 1999). Because of this widening of the scope of analysis, the point of interest for understanding cognitive activity becomes the actors, the tools and the rules that guide work towards the accomplishment of shared goals to enable effective system behavior. In the ICU, I was interested to discover how physicians rely on their material, technological and social resources to make decisions, how those resources shaped their decision-making activity, and the complications that were introduced by the relationship between information in the external environment and their expert decision needs.

To study this, my research was informed through the theoretical lens of distributed cognition (Hutchins, 1995). The theory of distributed cognition views cognitive activity as something more than what happens within the brain of an individual. Rather, cognitive activity is the result of interactions and relationships among the brain, body, and external environment (Hutchins, 1995). In my investigations, the activity system comprised those elements that bore directly on the daily episodes of clinical decision-making.

- The paper resources (e.g., the chart, admission note, daily progress notes, nursing flowsheet),
- Digital interfaces (e.g., lab results page, bedside monitors, clinical documentation pages, order-entry page),
- Clinical actors (e.g., nurses, physicians, residents),
- Communications (e.g., telephone calls, verbal exchanges, messages) and
- Rules or understandings (e.g., rounds are at 8:30am, the MRP – 'Most Responsible Physicians' is the physician who is charged with ultimate decision-making authority)

Methodologically, the study of decision-making within the wider information landscape of the ICU necessitates a qualitative approach that can illuminate the actual use of information resources, and highlight the role of contextual influences on decision-making (Greenhalgh & Swinglehurst, 2011; Laxmisan et al., 2007; Wears & Berg, 2005). I conducted a cognitive ethnography over the course of a five-month period (Oct 24th 2016 to Feb 24th, 2017) in an ICU based in Ontario, Canada. The data collected included over 450 hours of participant observation, which yielded over 400 pages of field notes, 49 interviews, and dozens of photographs of artifacts. Cognitive ethnography follows the qualitative methods of ethnography, while retaining the analytical framework of cognitive science (Perry, 1997; Williams, 2006). It is like traditional ethnography in that it relies on participant observation, interviewing, and artifact analysis to understand the meanings and cultural understandings to provide rich insights and "thick description" of a particular setting or cultural group (Geertz, 1973; Williams, 2006). While cognitive ethnography appropriates many of the elements of traditional ethnography, it uses them in a framework of cognitive science, "seeking to combine science and meaning making within the same approach" (Savin-Baden & Major, 2013). Rather than cutting context out, and seeking to isolate and control cognitive phenomena, like traditional methods in cognitive science, cognitive ethnography uses the environment as a point of departure for investigating cognitive activity (Perry, 1997).

My analyses were organized around episodes of clinical decision-making. During these episodes, as physicians were confronted with clinical problems or questions, they would seek to access and utilize the resources available to them in order to produce a decision outcome. Sometimes a decision could be reached within a few moments – after a check of the chart, or phone call to a colleague, while other times, decisions would take several days, emerging only after information from many independent resources were collected, organized and contemplated. Focusing on episodes of clinical decision-making gave me the opportunity to hone in on the interactions among the information resources, how they were mobilized and coordinated in support of a decision-making goal, and what effect the organization of resources had on decision-making.

Contributions

The central motivation underlying this dissertation is to explore the consequences of a systemic, distributed conception of cognition and decision-making as it relates to the design of information flow that supports decision making in medical environments. My findings highlight that information resources often did not support the thinking and decision-making needs of the clinical staff they intended to. Information resources were often objectivist, static, individualistic, and inflexible, failing to support the dynamic and distributed character of expertise decision-making. I observed many instances where information resources were well-suited to particular tasks or aspects of decision-making narrowly considered, yet that produced systemic consequences when considered at the level of the whole activity system of the ICU.

To provide an overview of my findings, information resources in the ICU often prioritized information that was highly standardized and structured, and in this vein, they tended to be static and inflexible in presentation, emphasizing the objectivity and discreteness of patient details. The resources also tended to be structured and pre-arranged around clearly intended clinical activities (often those that were administratively or legally mandated; Rosenbloom et al., 2011). Yet while consistent access to information about the objective clinical condition of the patient is helpful, physicians needed information to be more centered around their dynamic thinking needs, rather than around the patient or discrete clinical activities. Often the meaning of an objective piece of information would only become clear when placed in the context of other pieces of information that could be difficult to access. Physician's thinking was highly multifaceted and layered. Their questions could deal simultaneously with several issues within a single scope - the individual patient, the clinical problem, and particular areas of medical knowledge (Smith, 1996). Their thinking could also be organized at several levels of abstraction simultaneously, any of which could be foregrounded or backgrounded at any moment (Patel, Kaufman & Kannampallil, 2013). Hence, the decision needs of physicians were extremely dynamic, requiring quick access to highly layered and elaborated sources of information, and the information resources of the ICU, far from

keeping up, would often punctuate, interrupt, and distract decision-making (this is consistent with findings in existing literature, Patel et al., 2009).

To acquire the kind of layered, elaborate and contextually meaningful information that physicians needed, they would often be forced to conduct lengthy navigations through the information resources (e.g., clinical notes, results review page, flowsheets, etc…). These information resources were, in general, unresponsive to navigation – they were inflexible in their content and the level of detail with which they represented information, they did not support page transitions and there was an overall omission in supporting the *processes* of decision-making. In response to these difficulties associated with information design, I found that physicians compensated through a number of distinct strategies, including using personal paper worksheets to keep track of information, engaging in mobility work, relying on interpersonal communication with colleagues, and satisficing or simplifying decision-making by taking advantage of information that was available opportunistically. Yet, their compensation strategies, while being helpful in some respects, also produced a number of inadvertent consequences across the ICU that made decision-making more difficult. Most notably, because their information resources did not satisfy the dynamism and range of their decision needs, physicians were led to seek information through a number of ancillary channels – such as interpersonal communications and transitional artifacts. These additional channels of information, subject to little standardization, would be overly used and heavily relied on, and as a result they would contribute to a culture of interruption, multitasking, and information overload. Hence, the information measure (including information technology) that was intended to support decision-making, inadvertently contributed to the opposite outcome of making decision-making more difficult.

Dissertation Outline

The remainder of this thesis is organized as follows. Chapter two presents an overview of medical decision-making, moving from traditional and classical models of decision-making, to decision-making from the perspective of the theory of distributed cognition. The chapter highlights a range of influences that information resources in the ICU have

on decision-making. Chapter 3 presents the methodology of cognitive ethnography and how I utilized it in my ICU field work. In Chapter 4, I present the findings of my field work, focusing specifically on the ways that information is used in decision-making, the misalignments between the characteristics of information as they are used in decision-making, and how these misalignments are overcome or compensated for. In my final chapter, I discuss my findings in light of current literature, stating the contributions and limitations of this work, and suggesting directions for future research.

Chapter 2: Theory and Overview of Previous Research

In this chapter, I will introduce the traditional theories of medical decision-making, criticisms of it, and then elaborate on theory of distributed cognition as an approach to the study of medical decision-making. I will elaborate on the systemic and extra-individual factors that come to light through investigating medical decision-making through the lens of distributed cognition.

Traditional Medical Decision-Making

Understanding the thought processes involved in clinical reasoning in order to promote more effective practices has been the subject of concern for nearly a century (Osler, 1906). In recent decades, research in medical diagnosis and decision-making, adopting conceptual and methodological tools from cognitive science, decision science, probability theory and utility theory, has produced two main approaches to modern medical decision-making (Elstein & Schwarz, 2002; Hammond, 2000; Patel, Arocha & Kaufman, 2001). Despite major differences, which will be briefly summarized here, both approaches to decision-making share in common a dual focus on the cognitive characteristics of tasks and the study of individual human performance.

The decision-analytic approach to medical decision-making uses formal quantitative models of inference and decision-making as the standard of human judgment (Patel, Arocha & Kaufman, 2001). This approach to decision-making holds practitioners to the standard of empirical accuracy, and is a form of probabilistic utilitarianism (Hammond, 2000; Falzer, 2004). The mathematical model of choice in decision-analytic approach is Bayes' theorem, which provides the normative model for how physicians should reason, while a large body of research identifies the reasoning fallacies and biases that lead practitioners away from the standard of judgment. For example, research in this area has shown that physician decision-making is subject to probability transformations, where the weight of probabilities is systematically misjudged, overweighting low probabilities and underweighting high probabilities. This misjudgment would explain why the difference between 99% and 100% is subjectively greater than the difference between 60% and 61%

(Tversky & Kahneman, 1992; Elstein & Schwarz, 2002).

The decision-analytic approach has been successfully applied in a number of areas of clinical medicine, most notably evidence-based medicine (Elstein, 2001; Falzer, 2004). Evidence-based medicine has sought, in this regard, to teach Bayesian reasoning skills to physicians, to enable them to interpret how medical evidence bears on their clinical evaluations, to properly weigh and compare probabilities, and to update their assessments of decision outcomes as new information becomes available (Elstein & Schwarz, 2002; Hunink, Glasziou, Siegel, Weeks, Pliskin, Elstein et al, 2001). While there has been tremendous success in applying decision-making research through evidence-based medicine, leading, for example, to the development of numerous clinical practice guidelines, computer-based decision aids, cost-effectiveness analyses, and comparative effectiveness studies (Sox, Higgins & Owens, 2013), there has also emerged some difficulty in using the decision-making approach as the basis for clinical judgment in complex care environments. Taking the decision-analytic approach as the exclusive model of decision-making has led to criticisms of the psychological assumptions that undergird the traditional understanding of evidence-based decision-making in general (Goldenberg, 2006; Williams & Garner, 2002).

Another approach to medical decision-making, originating in the work of Newell & Simon (1972) on problem solving, is the information-processing approach, which aims to describe reasoning by expert physicians in order to improve medical education (Norman, 2005). The standard of decision-making in this case is the use of logic and internal rational consistency as the basis of good clinical practice, rather than empirically-oriented statistical models (Schwartz & Griffin, 2012). This perspective developed a vision of medical reasoning as a process of hypothesis testing, which serves as a basis to guide the search and collection of data, and to eliminate incongruent hypotheses as new information comes to light. Expert physicians differ from novices in the quality of their hypotheses, their ability to develop diagnostic plans, and their ability to move beyond data collection to considering hypothetical possibilities. Novices tend to collect more data, but ignore, misunderstand, or misinterpret findings, while experts have been found

to be too economical in collecting data, yet accurately interpret what is there (Elstein, Schulman & Sprafka, 1978). Later research showing the speed and efficiency of expert reasoning ruled out explicit hypothesis testing as a basis of clinical reasoning strategy, and showed some cases where the strategy employed resembles instances of pattern recognition, categorization, or even analogical reasoning (Hofstaedter & Sander, 2013). Expert physicians in this view build up, through education and clinical experience, a more diversified and abstract set of semantic relations – networks – that link the features of clinical problems to diagnostic knowledge learned through education and experience (Norman, 2005). As a result, this approach stresses the development of these mental models as the basis of strong clinical performance (Schwartz & Griffin, 2012).

Critiques of traditional medical decision-making

Although the traditional approach is still dominant in the field of medical decision-making, conceptual problems highlighted within cognitive science, and difficulties squaring traditional decision-making with the real-life needs of physicians have led to calls for new approaches to decision-making. Criticisms of traditional models of decision-making centered around two main axes: Firstly, traditional decision-making is thought of as too abstract, linear, and objectivist, and secondly, traditional decision-making locates decisions exclusively within the mental structures and contents of individuals.

Decision-making as abstract, linear, and objective

Traditional decision-making research has been criticized for being overly abstract, linear and objectivist. In short, in complex clinical situations, decision-making displays aspects of complexity (Wears, 2012), which are not adequately supported by interventions that assume an objectivist stance towards them. Simply providing decision protocols or guidelines, while helpful, sidesteps entirely the open-ended, exploratory, subjective, or ambiguous aspects of thinking that are part of thinking in the 'real world'. Traditional research derives its inspiration from models of the human mind as a logic engine or computer, which receives numerical inputs about the expected probabilities and utilities of treatments, processes them according to a pre-specified formula, and selects the 'optimal' behavioural output (Falzer, 2004; Sedig, Parsons, Naimi & Willoughby, 2015).

Rationality in this context is identified with choosing the best option that leads to the highest expectation of value. More than providing support for the objective and universal aspects of decision-making, physicians also need support for the particular characteristics of decision-making by the light of the patient, practitioner or situation (Fackler, et al. 2008; Falzer, 2004; Smith, 1996).

Weick, Sutcliffe and Obstfeld (2005, p. 412) articulate this point about medical sensemaking, which may be equally applied to medical thinking and decision-making more generally: "medical sensemaking is as much a matter of thinking that is acted out conversationally in the world as it is a matter of knowledge and technique applied to the world. Nurses and physicians, like everyone else, make sense of acting thinkingly, which means that they simultaneously interpret their knowledge with trusted frameworks, yet mistrust those very same frameworks by testing new frameworks and new interpretations. The underlying assumption in each case is that ignorance and knowledge coexist which means that adaptive sensemaking both honors and rejects the past, which means that in medical work, as in all work, people face evolving complexity."

Following this theme, Goldenberg (2006) argues that evidence-based medicine maintains an antiquated understanding of medical judgment and the evidence that supports it. In her view, medical judgments cannot stand or fall in the light of objectively constructed evidence. Rather than increasing objectivity, attempts to hold medical decision-making to the standards of technical rationality alone, merely obscure subjectivity (Goldenberg, 2006). Greenhalgh & Wieringa (2011) have argued that more attention needs to be paid to the subjectivity of medical judgment, and that the ambiguity and unpredictability inherent in medical decision-making should be allowed for, and engaged with on their own terms. Whether arising out of incomplete, fuzzy or difficult to interpret information, multifaceted situations, or complications in the decision process itself, the outcome of a decision process may not follow linearly from the evidence or protocols designed to support it (Gabbay & le May, 2010; Greenhalgh & Wieringa, 2011).

Outside of medical research, seminal research from science and technology studies has shown that abstract and formulaic descriptions of work can never encompass the contingencies and complexities of real work (Orr, 1996; Suchman, 2007). This has directed research away from canonical descriptions of clinical practice and towards the actual use of plans, formulae and other abstract or static representations of work by physicians and other medical professionals (Brown & Duguid, 1991). The emphasis on *actual use* of information in real time highlights the fact that no matter how objective, invariant, universal and scientific information is, it still relies on physician judgment to contextualize it, render it useful, and correlate it to the local needs of care situations (Constantinides & Barrett, 2012; Berg, 2003; Berg & Goorman, 1999). This process of contextualization defies complete standardization (Greenhalgh et al., 2009). As Star and Strauss (1999) warn, forcing abstract representations of work and cognition onto daily practice "may kill the very processes which are the target of support, by destroying naturally occurring information exchange, stories, and networks".

To support medical decision-making requires us to step beyond formal representations of work and cognition to support the processes of clinical work that allow physicians to think and make decisions in real time and space.

Information as Object
If medical decision-making is conceived as following an objective, linear protocol, then the conception of information as an object, which must fit neatly into the protocol follows naturally. Hence, information as conceived relative to medical decision-making is often reified, treated as a concrete resource, 'object', 'thing', or property that inheres within objects (Hutchins, 2010; Newell, Robertson, Scarborough & Swan, 2009; Østerlund & Carlile, 2005). This reification influences our approach to the design, representation, and provision of that information: When knowledge is reified, strategies to improve medical decision-making focus on providing physicians access to discrete objects that contain information, whether a new skill, fact, piece of evidence, document, or computer program, assuming that the meaning of information will be stable across time, place, and the recipient (Newell et al., 2009). Greenhalgh & Wieringa (2011) point out that because medical knowledge is usually understood as a tangible resource, research and practice

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often assumes that it can be used like to any other material object: it can be 'divided', 'pushed', 'pulled', 'channeled', 'summarized' and 'molded' to fit its destinations. Within evidence-based medicine, a growing body of interdisciplinary literature leverages a similar argument against 'commodified' or 'operationalized' knowledge use (Greig, Entwistle & Beech, 2012; Greenhalgh, Potts, Wong, Bark, & Swinglehurst, 2009; Greenhalgh, Robert, Macfarlane, Bate, & Kyriakidou, 2004; Nicolini, Powell, Conville, & Martinez-Solano, 2008).

If information is an object, then we can study it as we study objects: focusing on the reducible and invariant properties that characterize objects that contain information. This approach, while it has its merits, effectively excludes the possibility that knowledge can behave as a relationship, capacity, subject, or action, and overemphasizes the explicit, stable, predictable aspects of information (Feldman & Orlikowski, 2011; Kallinikos, 2011; Tsoukas, 2004). This 'object-oriented' view, focuses attention on the characteristics of information independently of how they interact with the characteristics of other information objects and processes (e.g., of how interaction with human actors changes information). For example, research in medical information often focuses on the location of information, its quality, and how it can be accessed, yet without clarifying principles about how these characteristics of information vary according to the person using them, or the setting in which they are used (Sedig, Parsons, Naimi & Willoughby, 2015).

While recent studies in information science and knowledge management have moved away from an object-centric view towards an interaction-centric view (Marchionini, 2008; Baker & Bowker, 2007), blurring clear boundaries between information its environment, and way it is used, these studies have not had a real and lasting influence in mainstream medical decision-making (Gabbay & le May, 2010).

Individualism and Context in Medical Decision-Making
A growing and interdisciplinary body of research is exploring what the locus of decision-making should be (May, Johnson & Finch, 2016). Currently, expertise is produced and

decisions are supported at the level of the individual practitioner (Bleakley, 2006; Boreham, 2004; Hafferty & Levinson, 2008; Lingard, 2012; Miller et al., 2010; Stead, Searle, Fessler, Smith & Shortliffe, 2011). Each doctor is the master of their own scope of practice and is responsible for their own specialized population. Yet as the nature of medical problems change, super-sub-specialization and the individualistic arrangement of medical expertise and information becomes unsatisfactory (Gawande, 2010; Miller et al., 2010; Stead et al., 2011). To help overcome the limitations of the scope of their own expertise, and those of their information resources, the medical community has sought to support practitioners in dealing with the ever-growing complexity of medical problems by assisting them to reflect broadly upon the 'context' of medical decisions.

Across the field of medical decision-making, there has long been consensus that contextual factors should enter into decision-making (Gray, 2009; Sackett, Rosenberg, Gray, Haynes & Richardson, 1996), yet what context means, and how it influences decision-making has not been the subject of agreement. Because of its emphasis on the contents and structure of the individual mind, the concept of 'context' dwells uncomfortably within traditional decision-making. When traditional decision-making does seek to lend explanatory force to extra-individual factors, this is done by representing or encoding those factors within the mental contents of the individual (Hazelhurst, Gorman & McMullen, 2008). For example, some measures of context can be incorporated into certain terms of Bayes' theorem, which is used as the standard of individual medical decision-making. Hence, while traditional decision-making doesn't necessarily exclude the possibility that context may play a role in the outcome of decisions, it does assume that any decision outcome must be represented within the thoughts of an individual practitioner. The consequence is that, while context has been the subject of much debate and discussion within medical decision-making, the espoused assumptions inevitably lead to an impoverished notion of context, which retains primacy for the individual, and only examines context insofar as it is encoded in the mental structures of individual practitioners (Hazelhurst, Gorman & McMullen, 2008).

In complex decision-making scenarios, the input and processing of information demands more than any one person can manage alone, and hence decisions are decentered (Coiera, 2015). That is, they are the product of teams of practitioners, tools and technologies working together (Bleakley, 2006; Lingard, 2012; Boreham, 2004). As Weick, Sutcliffe and Obstfeld (2005) have observed: "If knowledge about the correctness of treatment unfolds gradually, then knowledge of this unfolding sense is not located just inside the head of the nurse or physician. Instead, the locus is system wide and is realized in stronger or weaker coordination and information distribution among interdependent healthcare workers". This puts a higher expectation on the coordinative abilities of the healthcare communities making decisions. These include communication and the ability to share and integrate information, create common ground, perspective take, communicate complex pictures of care, and other activities related to collective competence (Lingard, 2012; Boreham, 2004).

While a great deal of research has been done in these areas, they are usually seen in the medical community as distinct and disconnected from the capacity to make decisions. As a result decision support efforts in the medical community are not adequately suited to the kinds of decentered decision-making required in the modern healthcare system, where decisions are not the product of the lone physician, and where they are inextricably tied to the people, paper an technologies that shape them, frame them, and make them possible.

As science advances and medical evidence expands, as new technologies emerge, then medical decision-making will be informed by scales of information undreamt of in the past. Medical problems will become inherently reliant upon technology, and a new relationship will have to be envisioned between medical practitioners and the decisions they make (Stead et al., 2011). Medical problems will simply not be tamed by the expertise of individuals, no matter how wide the scope of their training. The complexity of these decisions require the people and the technologies they use to come together to collectively see the whole scope of a decision, than relying on specialization, where each practitioner has only a subset of the data, and is responsible for a segment or aspect of treatment and care (Stead et al., 2011).

To summarize, traditional accounts of medical decision-making have made significant advances in understanding how individual practitioners think, reason, and gain expertise, yet they consistently limit the scope of decision-making, and represent it formulaically. Because of this, the issue of how practitioners manipulate and contextualize information to make it relevant to the idiosyncratic needs of their situations in real time, and how the whole clinical team comes together to solve a problem have not been adequately studied (being limited by some of the assumptions of medical decision-making). In the next section, I introduce the theory of distributed cognition, an influential theory of ecological cognition (Hutchins, 1995; 2010), which has sought to overcome these limitations.

Theory of Distributed Cognition

The framework of distributed cognition has its roots in cognitive anthropology, cognitive science, and the computer-supported cooperative work (CSCW) community (Hazlehurst, Gorman & McMullen, 2008). Rather than viewing cognition as simply something that happens within the brain of an individual, or as something that is achieved by following a linear protocol, the more recent, 'distributed' view conceptualizes cognitive activity as the result of interactions and relationships among the brain, body, and external environment (Hutchins, 1995). Specifically, at the heart of cognitive activity is the capacity to produce a functional relationship among the information-bearing resources, or representational resources, in an environment to effectively meet the demands of a medical task. From this perspective, decision-making is accomplished through the aid of representational media (including actors, tools, rules and understandings) that are inscribed in the technological, material, or social channels in which information flows. To accomplish complex work tasks, humans 'informise' their environments with representations (Pennathur, 2013). As a result, understanding how complex cognitive work is accomplished requires us to expand the unit of analysis for cognitive activities beyond the individual to the activity system, made up of the representational media that contribute to the performance of a cognitive activity (Clark, 2008; Hazlehurst, Gorman & McMullen, 2008; Hutchins, 1995; Kirsh, 1999).

Complex cognitive tasks rely on representations, and can rarely be accomplished through the agency of a single individual. Representations encode and stabilize information in order that human beings can engage with it (Kirsh, 2003). In care environments, representational media, such as computers, labels, forms, or verbal utterances, store, process, and display representations suited to the needs of complex medical decision making (Norman, 1991). These representations are manifest in particular configurations of information. For example, a single blood pressure reading (the information) can be configured in various ways: numerically, through different graphical arrays, or linguistically, each of which would constitute a separate representational state of the same information (Sedig, Parsons, Naimi & Willoughby, 2015).

To support the array of activities that make up an activity system, representations are propagated (flow) within an activity system, from one medium to another, through processes that act upon the configuration of information. For example, physician charting of the daily progress notes by clinical staff in the ICU serves to encode up to date representations in a predictable place and accessible format. Charting, then, serves systemic needs of the clinical team by regularly moving several pieces of information into a stable enough form that the clinical team can use it for the variety of their needs across time. These representations, shape human thought and activity and it is important that they are moved to right place, at the right time, in the right configuration to meet the decision-making needs of the clinical team. This propagation, or flow, of representations accounts for the cognitive performance of the activity system as a whole, and thus serves as the point of interest for investigating the features that organize the system (Hazlehurst, Gorman & McMullen, 2008; Hutchins, 1995).

In distributed cognition, the concept of coordination is used to understand the effectiveness of information flow and organization within an activity system (Hazlehurst et al., 2008; Hutchins, 1995). Coordination implies mutual interdependence, fit, coherence, and seamless information flow among the information resources of an activity system, where representational states are propagated throughout the system so as to enable effective system behavior (Fidel, 2012; Hutchins, 1995; Kirsh, 1999). Coordination is not a static state. It implies ongoing accomplishment as the system meets

new challenges and demands. Coordination also never works upon a blank slate – it is situated in time and space, and predicated on a history of ordered configurations of representations within the system (Ellingsen & Monteiro, 2003a; Hutchins, 1993; Kirsh, 1999; 2001; Okhuysen & Bechky, 2009).

While there is a robust body of research that studies the cognitive dimensions of work in organizational settings there remains a paucity of research examining how information resources collectively organized within the activity system support the full range of intellectual needs that characterize ICU decision-making.

In this context, as the lens to understand and support medical decision-making widens to include the range of information resources and their interactions and interdependencies, the questions that arises are:

- *How do the information resources in the ICU facilitate or hinder the various cognitive tasks associated with dynamic and distributed decision-making?*
- *How do physicians compensate for the organization of information resources when they are not aligned with their decision-making needs?*

In ICU environments, clinical decision-making is the product of paper resources, technologies and people working together within an activity system towards a common goal. While research conducted concerning ICU decision-making is rare from the perspective of distributed cognition, there is nonetheless a great deal of insight to be gained about the difficulties that arise when people, paper and technologies come together to contribute to decision-making. In the remainder of this section, I provide a brief overview of the difficulties that arise in using paper, technologies and colleagues as information resources in the goal of making medical decisions.

How people, paper, and technologies contribute to decisions in the ICU

According to Wears (2012) the dominant approaches to supporting clinical decision-making through information have been characterized by an orientation of technical rationality and scientific reductionism. Nowhere is this better illustrated than in the

efforts to build information technologies, which are the main pillar of the decision-support strategy in hospital and critical care environments (Wears & Berg, 2005). A major finding, in this connection, is the way decision-making activities are supported through centralized vendor-based solutions (CPOE, EHR, etc…), which often fail to account sufficiently for the complexity and nuance of clinical work (Ash, Berg & Coiera, 2004; Campbell, Sittig, Ash, Guappone & Dykstra, 2006; Patel, Zhang, Yoskowitz, Green and Sayan, 2008). In fact, the formal way that information is provided through these systems can actually make clinicians perform worse than they would have without the 'support' (Karsh, Weinger, Abbott & Wears, 2010; Tierney, 2001). This can happen when, for example, HITs force clinicians to navigate several screens or menus, search unduly for needed resources, declutter high volume and dense interfaces (Ahmed, Chandra, Herasevich, Gajic & Pickering, 2011), and demand multiple sign-on requirements (Nemeth, Nunnally, O'Connor, Klock & Cook, 2004; Nemeth, O'Connor, Klock & Cook, 2006). Moreover, a number of scholars agree that current approaches to support of clinical decision-making through IT are insufficiently attuned to situated and contextual information needs that arise in real clinical practice (Ellingsen and Monteiro, 2003a).

To adapt to the linearity introduced by formal workflow support systems, Chen (2010) shows how practitioners adopt a range of parallel informal documentation practices that assist them to use formal, electronic information resources. Specifically, to accomplish their electronic charting in the emergency department, doctors and nurses used transitional artifacts (e.g., whiteboards, paper notes, sticky notes) to compensate for the non-sequential information flow during patient care. Chen's (2010) results showed that the EMR system demanded information input in a patient-centric way, rather than a workflow-centric way, and as a result practitioners suffered from a lack of support in documenting procedural information. This lack of support for recording the procedural aspects of clinical information work led to decreased efficiency and increased workflow, which practitioners sought to overcome with informal resources. Similar to Chen (2010), other studies also show that practitioners compensate for the rigidity of information

technologies through more flexible (and usually paper-based) artifacts paper (Hardey, Payne, & Coleman, 2000; Hardstone, Hartswood & Rees, 2004; Fitzpatrick, 2004).

Coiera (2013) studied how practitioners supplement the information provided through technologies by annotating, with notes, images, permanent signs or digital texts, the physical workspace around them. He found that the annotations created around information technologies serve to enhance the fitness of those technologies in four ways: Firstly, they make up for missing or insufficient information, secondly, they support local variations, thirdly, they restrain local variation/ preventing unexpected or undesirable user behaviour, and fourthly, they support the repurposing of spaces or tools for uses other than their intended purposes. Hence, annotations of information technologies help practitioners contextualize or use information delivered through information technology "in the logic of here" (Suchman, 2007).

Along with the linear and reductionist way that information is presented comes the problems associated with the accessibility of information. Modern hospital environments are often characterized by fragmentation – the story of care not being found in any one place or with one person, but distributed such that one part may be in the progress notes, another in the flowsheet, yet another in the monitor, with the family doctor, and so on (Ellingsen & Monteiro, 2003a). To overcome the difficulties associated with finding information on this fragmented landscape, some research shows that clinicians create and use 'bundles' of information resources – organized and selective collections of task-specific information - to make using those resources more suitable to clinical work (Ash, Gorman, Lavelle, Lyman, Delacambre…& Bowers, 2000). To creating bundles and facilitate decision-making, clinicians engage in 'mobility work', in that they "…move from patient to patient, from place to place, from one piece of technology to another, and from one source of information to another to make the right configuration of people, places, resources and knowledge emerge" (Bardram and Bossen, 2005, p. 150-1). The authors note that, even though EMRs plays an obvious role in overcoming physical barriers to using information resources, they nonetheless impose their own barriers, and sometimes make the patient record paradoxically less mobile (Bardram & Bossen, 2005).

Just as Chen's (2010) study (above) showed how clinicians developed and used provisional forms of information encoded in transitional artifacts to overcome overly-formal information resources, Bardram and Bossens' studies show how clinicians use informal means (i.e. - printing the electronic record, manually carrying resources, etc…) to achieve co-location and enhance portability of the relevant resources (Bardram, 2009; Bardram & Bossen, 2005).

Another area where the standard presentations of information in workflow systems can present an issue is where a medical decision demands the input of several physicians simultaneously, and hence collaboration and common exploration of a problem is required. In a series of articles, Reddy, Dourish & Pratt (2001; 2006) explored the utility of information technologies in supporting and coordinating the diverse work of practitioners treating a single patient. Their findings show that information stored on a technological platform, insofar as it supports the specialized representation of information to different practitioner groups, allowed practitioners to collaborate more effectively than when information was stored on paper (where information and its representation are not decoupled). The ability to decouple information and its representation, and display the same information differently to different practitioners can support collaboration, helping clinicians to abstract information away of their own activity, and more easily contextualize it in the work of a colleague. This supports the ability to step away from your own work concerns, visualize the whole process of medical care, better anticipate mutual concerns, and facilitate better coordination. Ellingsen & Monteiro (2003b) echo this finding by pointing out that the same information, yet presented in different ways across different clinician groups serves to enhance perspective-taking (Boland & Tenkasi, 1995), and a more robust awareness of the colleague's mental models. In turn this assists the clinical team to better coordinate their activities, and build a more comprehensive and nuanced picture of patient care when needed (Gittell, 2006; Gittell, Seidner & Wimbush, 2010). The upshot of this area of research might be a warning against premature purifications of the differences in information representation, which rely too rigidly on a universal perspective (Ellingsen & Monteiro, 2003; Greenhalgh, Potts, Wong, Bark & Swinglehurst, 2009; Wears, 2012).

Instead, a balance must be struck between the aspects of decision-making are universal (and hence would benefit from and rigid and standardized approach to information representation), and which aspects of decision-making are contextual (which would be better supported through open, flexible and adaptable representations). According to Greenhalgh, Potts, Wong, Bark and Swinglehurst (2009) this tension between standardization and flexibility can in principle never be resolved and must be actively managed in every implementation of decision support.

When information resources are not adapted to the actual needs of decision-making in the ICU (e.g., irrelevant, uninformative, or unactionable), one major strategy that clinicians rely on is to seek out information from their clinical colleagues. In seminal research, Covell, Uman and Manning (1985) demonstrated that a physician's colleagues are their primary source of information, rather than any formal documented sources (a finding that has proven robust in hospital settings despite the changes in information landscape over the decades, Montgomery, 2005; Sweenen et al., 2013). In the modern hospital environment, physician's remain each other's primary source of information, but the means of clinical communication have proliferated, including face-to-face conversations, opportunistic exchanges, telephone calls, emails, voicemails, text and other electronic messages. In this context research has demonstrated that physicians can struggle with clinical communications as a consequence of many factors: (1) juggling too many sources of communication, where each may display subtle differences of the information, (2) channels of communication that distort or otherwise introduce noise into the message, rendering clinical communications low in quality and relevance, and (3) channels are often ill-suited to physician's needs of establishing common ground. Because of these problems, sharing information through interpersonal communications can make the overall experience of clinical decision-making more difficult. Especially in acute care settings, interpersonal communications contribute to an environment of interruption-driven work, which can have negative consequences on decision-making (physicians are interrupted approximately every 9 minutes, and nurses every 14 minutes, Laxmisan et al., 2009; Parker & Coiera, 2000).

Two major reasons why EMRs and other workflow support systems can make clinical work harder are firstly, their inability to express rich information in little space – a characteristic that might be called *informativeness*. Informative representations of information have high value in critical care contexts, where work demands rich information in a fast-paced environment. The second reason that undermines the value of EMRs is their inability to be altered and modulated by the practitioners who use them – a characteristic that might be labeled *inflexibility*. Both of the characteristics are illustrated by research that Xiao, Schenkel, Faraj, Mackenzie & Moss (2007) have undertaken, which analyze the continuing relevance and use of the whiteboard in ICUs across North America. They argue that white board allows clinicians to convey rich information through nuanced presentation of data. For example, practitioners employ a number of techniques, including striking through, using different colored pens, or annotating with distinct character fonts or sizes to signal meaningful differences in patient care and workflow. The ability to annotate and express subtle differences and convey highly elaborate and meaningful information because it is difficult to replicate in EMR systems, makes them more suitable for the dynamic purposes of decision-making in the ICU. Furthermore, because it is the practitioners themselves who retain primary agency in what to write down, being limited only by the norms of communicate among peers, using the whiteboard can be less cumbersome.

Similar to the problems that beset formal IT systems, some formalized paper-based resources in ICUs also suffer to support workflow and clinical reasoning. In their qualitative research, Varpio et al (2015) examined the effects of ICU flowsheets on clinical reasoning. They highlight that the recording of patient data in a single sheet supported reference and finding the objective facts related to the patient, yet rendered complex medical reasoning more difficult. Putting the patients story together, chronologically linking the events together, reasoning about the causal effect of interventions, were all difficult to conclude from the way information was integrated and presented. In this sense, the presentation of objective data obscured the contextual relevance of the data, leading clinicians to report a lack of awareness of the patient's evolving status, a higher cognitive workload, and a loss of support mechanisms for clinical reasoning. For the authors, the key issue in supporting medical decision-making

is facilitating the ability to see connectivity among the information resources. Their findings warn against overly-deconstructed presentations of information, which leave the clinical team with "massive amounts of data fragments, but without an interconnected whole" (Varpio et al. 2015, p. 482). This trend in data presentation can prove problematic, especially considering the well-documented finding that too much data, or data that is too fragmentary tends to undermine decision-making performance (Klein, 2004; Tierney, 2001).

Rosenbloom et al (2011) explore this same issue in the context of clinical notes, which are those documents that summarize the interactions between care providers and patients. They identify a tension between, on the one hand, the expressivity of clinical documentation, the extent to which the documentation provides rich information about a provider's impressions, reasoning, level of concern, and uncertainty about the treatment plan, and on the other hand, structured clinical documentation, which supports readability and reuse of data from clinical notes. On the whole, busy clinicians tend to prefer the former, while those reusing data prefer the latter. The authors suggest that clinicians should be given the option to choose which documentation best expresses their practice needs.

One strategy that Varpio et al (2015) suggest to remedy the problems associated with using documents (such as flow sheets and clinical notes) is that more attention be paid to encoding information according to the principles of narrative construction, which highlight the interconnections or sequence among pieces of information. In complex situations, physicians organize information about a patient by invoking mentally stored models of illness, and simultaneously have to adapt and merge those mental models with unique characteristics of the situation (Fackler, et al., 2008). This relies on a bridging process – where abstract mental models stored in memory are merged with clinically relevant details coming from the environment. Narratives support complex thinking and decision-making because they allow practitioners to encode information in an efficient way – retaining the gist of clinical situations in terms of well known clinical stories or illness scripts (Montgomery, 2005; Charon, 2008). By allowing physicians to encode information at a high-level, focusing on the essential gist, narratives help physicians to

straddle the abstract and the concrete elements of a situation, and assist them to move more fluidly along an abstraction hierarchy (Patel, Arocha and Kaufman, 2001; Patel, Kaufman & Kannampallil, 2013). In turn, this can help physicians better investigate the possible explanations of clinical findings, better visualize possible clinical outcomes, and can support the organization, relevance, coherence, and level of abstraction of clinical thinking.

To summarize, the misconceptions that lie at the root of our traditional conception of decision-making manifest themselves in the paper, technologies and collegial resources that are provided to support decision-making. On the whole, research has illustrated that the provision of information in ICU environments pays insufficient attention to the actual complexity of ICU decision-making.

In making decisions, physicians and other clinicians rely on their information resources, which must be informative and flexible relative to their needs. In modern ICU environments, physicians need information that will support meaningful, nuanced, and well-elaborated decisions; they need information that will help them see connections between different aspects of the patient's story (social, historical, clinical, medical, and physiological); they also need information that will help them collaborate and see what other practitioners think; and finally, they need information that will help them tie general abstract information with the concrete facts in the here and now. The information available across paper, technologies, and colleagues is often uninformative and inflexible relative to these needs. Using the theory of distributed cognition can help us observe how physicians manipulate and use information resources available in the ICU in terms of their dynamic and distributed decision needs. Distributed cognition, more than other theories of social learning, help us to see the outer arrangements of people, paper and technology as reflections of the inner process that support decision-making (comparison, abstraction, navigation, focusing, seeing cause and effect, etc…). In the next section I present the methodology of cognitive ethnography, which I used as my data collection methodology.

Chapter 3 Methods

To study decision-making within the wider activity system of the ICU necessitates a qualitative approach that can illuminate the actual use of information resources, and highlight the role of contextual influences on decision-making (Greenhalgh & Swinglehurst, 2011; Laxmisan et al., 2007; Wears & Berg, 2005). This chapter reports on ethnographic research carried out over a five-month period (Oct 24th 2016 to Feb 24th, 2017) in an ICU based in Ontario, Canada (See Appendix 1 for Ethics Documentation). The data collected included over 450 hours of participant observation, which yielded over 400 pages of field notes, 49 interviews, and dozens of photographs of artifacts (this length of time spent in the ICU is commensurate with other medical cognitive ethnographies, which range from 2 months (Cohen et al., 2006), 200 hours (Xiao et al., 2007), 700 hours (Hazlehurst, McMullen & Gorman, 2003), and 9 months (Nemeth et al., 2004).

Cognitive Ethnography: Methodological framework

Cognitive ethnography, while drawing from the qualitative methods of ethnography and social science, retains the analytical framework of psychology and cognitive science (Perry, 1997; Williams, 2006). Firstly, in traditional ethnography, the ethnographer collects data through participant observation, interviewing, and artifact analysis to understand the meanings and cultural understandings that characterize a specific setting or cultural group (Williams, 2006). Ethnographical observation provides rich insights of the naturalistic environment, thought and behavior of a group of people through "thick description" (Bechky, 2006; Geertz, 1973). While traditional ethnography is concerned with the meanings and beliefs that a cultural group creates, cognitive ethnography is more interested in the information processes by which those meanings are created. That is, traditional ethnography might investigate the meaning of certain concepts, how they are understood, enacted, and their effect on culture and society, while cognitive ethnographers would seek to understand how different types of cognitive activity are

engaged in and accomplished. In this sense, cognitive ethnography, while drawing on an ethnographically-derived understanding of the culture, is more functional and extends ethnography towards process analysis of the dynamics of real life information flow (Williams, 2006).

Secondly, cognitive ethnography appropriates some of the elements of traditional ethnography while using them in a framework of cognitive science. Cognitive ethnography strikes a balance between methodologies grounded in social and cognitive traditions, and "seeks to combine science and meaning making within the same approach" (Savin-Baden & Major, 2013, p. 142). Because of this, cognitive ethnographic methods falls neither within a purely situated, participant-centered and subjective approach, nor within a purely reductionist, experimental and objective one (Ball & Ormerod, 2000). Cognitive ethnography is naturalistic in its approach, and is sensitive to how the environment influences cognitive activity. Rather than cutting context out, and seeking to isolate cognitive phenomena, like traditional methods in cognitive science, cognitive ethnography uses the environment as a point of departure for investigating cognitive activity (Perry, 1997). Cognitive ethnography also retains a degree of subjectivity, and a role for the observer, and objectivity, and an attempt to retain validity and reliability. Cognitive ethnographers must be reflexive and attempt to understand how their involvement in the research may influence it (Bourdieu & Waquant, 1992). Nonetheless there is still an assumption in cognitive ethnography that research data are not irreducibly personal and subjective. Because the approach to research in cognitive ethnography falls on a spectrum of objectivity and subjectivity, data and observations can retain a degree of both (Ball & Ormerod, 2000).

Because interpretive research is so interwoven with the biography and self of the researcher (Denzin, 1989), it is important to make the reader aware of the influence that my intellectual background had on data collection. My background as a psychologist (undergraduate studies in Psychology and Graduate studies in Cognitive Psychology) had a large effect on what struck me as phenomenon worthy of study in the ICU. While there was inevitably so much that would be of interest to social and health scientists of all

stripes and persuasions, my interest was invariably drawn to difficulties in processing information and using knowledge, both individually and collectively.

Methodological Focus on the Activity System

The focus on the activity system is a central methodological element of cognitive ethnography. In my investigations, I was careful in drawing the boundaries of inclusion and exclusion of the activity system. Conscious of the warning of Hutchins (2010, p. 706) that "every boundary placement makes some things easy to see, and others impossible to see", I spent much time observing the objects, people and processes that had a material effect on everyday decisions and was mindful to focus on interactions, relationships, and processes, rather than focusing on formal rules or objects in isolation.

The activity system that emerged from my observations was comprised of those elements that bore directly on the daily 'episodes' of clinical decision-making. These included, but were not limited to:

- The paper resources (e.g., the chart, admission note, daily progress notes, nursing flowsheet),
- Digital interfaces (e.g., lab results page, bedside monitors, clinical documentation pages, order-entry page),
- Clinical actors (e.g., nurses, physicians, residents),
- Communications tools (e.g., telephone calls, verbal exchanges, messages) and
- Rules or understandings about "how the ICU works" (e.g., 'rounds are at 8:30am', 'the Most Responsible Physician is charged has ultimate decision-making authority')

My analyses were organized around episodes of clinical decision-making. During these episodes, as physicians were confronted with clinical problems or questions, they would seek to access and utilize the resources available to them in order to produce a decision outcome. Sometimes a decision could be reached within a few moments – after a check of the chart, or phone call to a colleague, while other times, decisions would take several days, emerging only after information from many independent resources were collected,

organized and contemplated. Focusing on episodes of clinical decision-making gave me the opportunity to hone in on the interactions among the information resources, how they were mobilized and coordinated in support of a decision-making goal, and what effect the organization of resources had on decision-making.

In line with the activity system's resonance with complexity theory and nonlinearity of work and decision-making, I was committed in my analysis to holism and breadth of explanation, rather than clarity achieved through reductionism and simplicity (Bleakley, 2010). Hence, even when decision episodes appeared to consist merely of a few clicks or interactions with a screen, I was interested to understand how this 'micro-episode' was shaped by a wider scope of analysis – the conversations that preceded it, the technologies or routines that simplified it, or the presentation of information that prolonged it. In this way, I was committed to seeing decision-making as an open phenomenon, influenced in unpredictable ways by its environment, characterized by fuzzy boundaries, propelled forward by situated feedback, rather than design and plans. In this spirit, and insofar as it was possible, I sought to cut across traditional levels of analysis, and see something of the whole system in even minute episodes of decision-making (Bleakley, 2010; Crossan, Maurer & White, 2013).

In studying decision-making, I followed the advice of Laxmisan et al (2007, p. 802), that "decision-making should not be studied in isolation from other processes such as situation awareness, problem-solving, uncertainty management and the development of expertise". Rather than being a single activity, workflow or process, decision-making in the ICU involves managing, organizing and configuring an array of resources that facilitate information flow, and decision-making within this context emerges as an ongoing accomplishment, where the clinical team "inches forward step by step, layer by layer – arriving at reasonable and satisficing ways to act that never really looked like a decision" (Gabbay & Le May 2010, p. 53). In pursuit of this goal, I sought to understand the embeddedness of medical decisions within the context of the activity system of the ICU. The activity system here consists of all the clinical practitioners (nurses and

physicians) and information artifacts (flowsheets, electronic medical record, chart) that work together to plan and administer care for any single ICU decision episode.

To understand the embeddedness of medical decisions, my analysis was generally informed at three levels (see the rows of Figure 1): Firstly, I was cognizant of the overall goals of ICU care and the routines that directed the course of patient care (e.g., assess the patient, monitor the patient, plan care for the patient). Secondly, I was interested in the variety of tasks that were used to facilitate and arrange the movement of information so that those goals could be achieved (e.g., compare the blood pressure across the last 3 hours, understand the consequences of administering a medication, understand the significance of the patient's renewed bleeding). Thirdly, I sought to be aware of the information resources that were used in decision-making activities, the interactions and interdependencies among them, and how they would these interactions would play out in the everyday life of the ICU (e.g., physician place the chart by the results page, resident consistently checks every patient's blood flow after rounding on them). In all this, I kept an open eye to witness the material (its location, medium) and representational (text, verbal, images, graphical, audio, etc…) properties of information, whether there were barriers to their use, and how these barriers were overcome. In the figure below, I explicate the three levels of analysis (the rows) that informed my inquiries: I investigated the overall goals of the ICU as 'routines', which were instantiated and accomplished through tasks, and made possible by interactions between information resources. For a description of the ICU routines (the columns in the figure – assessment, monitoring, and planning), see the Findings section.

ICU Routines	Patient Assessment	Patient Monitoring	Planning
ICU Tasks that support routines	Assess historical health and recent issues; how chronic issues relate to active ones; expected interactions and clinical manifestations	Monitor and maintain overall health through clinical indicators; keep track of emerging issues	Explore interdependencies in the plan approach; understand consequences and trade-offs; anticipate outcomes and timelines.
Resources used to complete ICU tasks	Handoff from surgeon on admission; History in the chart & clindocs, CSRU admission note. Main responsibility: resident/fellow	Flowsheets, nursing assessment, investigations, Results review page (blood and lab work). Main responsibility: Bedside nurse, resident/ fellow	Progress notes, CPOE, conversations, phone calls, Main responsibility: Consultant, resident/fellow

Figure 1. Depicts the overall cognitive routines that contribute to ICU decision-making, some cognitive tasks associated with them, and the resources used in them.

Data Collection Tools and Techniques

In this section I provide an overview of the data collection techniques that I used in my cognitive ethnography, including interviews, observations and artifacts analyses.

Participant Recruitment and Interviews

Participants included the nurses, residents, fellows and consultants working in a cardiac intensive care unit. No patients were included in the research. I recruited all interviewees personally and directly, and administered an information and consent form (See Appendix 2). During my first three months in the ICU (from late October - late January), I conducted no interviews but relied on participant observations to better formulate and

hone my interview questions. My first interview was conducted on January 26th 2017 and the last one was completed March 30th 2017. In some cases, interviews were done immediately upon recruitment, while other times a meeting time had to be fixed. I conducted a total of 49 interviews (with 18 nurses, 9 residents, 7 fellows, and 15 consultants). These were done on the ward or in another convenient location (e.g., the hospital cafeteria or an office). Of these interviews, 44 were recorded and transcribed, while in the case of 5 interviews consent for audio recording was not given(and I relied instead on hand-written notes instead). The average interview duration was 30 minutes, with the shortest one lasting 6 minutes and the longest one 66 minutes (the total amount of recorded time was 22 hours). The range of interview durations was accounted for by the fact that I had to approach interviews in a variety of ways: At times opportunistic and directed towards a specific issue, and other times more formal or exploratory. For example, when an interesting patient case presented itself, or an unprecedented use of information technology, I would approach the bedside nurse after the fact and ask them about it. These interviews were in general much shorter. At times, I would approach several different practitioners about the same episode.

I used a semi-structured interview approach and followed a protocol that was divided into three parts (see Appendix 3). Firstly I began by introducing my background, interests, and the goals of the project. Here, I would seek to help them my interest in the provision of information in an activity system and medical decision-making. Secondly, I would ask them for insights about their own cognitive work: the work involved in charting, monitoring, assessment, investigations, establishing a working diagnosis, identifying active medical issues, or the influence of chronic issues on acute ones. I would ask them to identify the important aspects of their work, and those that are most challenging. Thirdly, I would focus on the influence the information resources and technology had on practitioner's cognitive work. For example, I would ask them about their use of the EMR system, the chart, the flowsheets, and how these supported or undermined the cognitive work in the ICU.

I spent a total of 450 hours in the ICU, on top of the dozens of hours conducting interviews, attending training sessions (e.g., hospital computer training sessions for medical students), participating in the teaching sessions of the clinical team (informal clinical education sessions), and other spaces where the medical staff would associate and learn together. In the ICU, I ensured that my observations would span all hours of the day (from rounds at 8:30am to 3:30pm) the evening (from rounds at 3:30pm to about 11pm), and overnight (11pm to 8:30am).

The ICU is a busy environment, with dozens of professionals, each doing their own particular job within the larger scope of clinical care. No one person in the ICU understands what everyone does, and as a result, a work culture emerges where practitioners focus on their own jobs, and don't worry too much about new faces. As an outsider, I relied on an observation approach that would allow me to interact with the practitioners where possible, while not interfering with the delivery of care (i.e., observer as participant; Atkinson & Hammersley, 1994). Within this approach, I employed two basic observation strategies. In the first case, I would choose a particular location to observe (e.g., a particular bed, the front desk, or the conference room). There, I would focus on the coming and going of staff, the intersection of different information resources, the usage patterns and the activities they would support. In the second case, I would shadow particular individuals (a consultant, fellow, resident or nurse), trying to understand their needs, and the reasons for their interactions with information resources.

I sought to understand which resources were used in decision-making, the relationship among those resources, and the flow of information across the resources that support decision-making. Because medical decision-making is dependent on medical expertise, it was often difficult for me to follow the details of the decisions being made. Where I could, I utilized a number of strategies to compensate for this. Firstly, when it was possible I would directly ask practitioners about the thought process they were engaged in. For example, when I observed that during rounds, consultants consistently look at every patient's flowsheet, I would ask to understand what information it conveyed.

Secondly, I was very interested in decision making under non-routine circumstances. For example, when patients were admitted outside of the routine admission process, the doctors and nurses had to externalize a variety of issues that were normally left tacit and invisible to the outsider. Another example was when patients with very rare conditions were being cared for, and the clinical team had to take time to discuss and plan many aspects of care that were usually habitual.

Analyses of Cognitive artifacts

Observing cognitive artifacts can provide a 'way in' to understanding the cognitive work of clinical teams (Nemeth et al, 2004). Artifacts can have a variety of effects on cognition: they can direct attention, influence the frame of decision-making, make invisible assumptions apparent, and limit the need for, or efforts required for abstraction (McLane et al., 2010). The ICU employs a range of cognitive artifacts, from whiteboards, schedules, manuals, charts, forms, computer systems, decision-support programs, guidelines, fact-sheets, and others. In my analysis of the cognitive artifacts of the ICU, I sought to understand only those cognitive artifacts that had were directly involved in storing, processing or displaying the information used in clinical decision-making.

While there are many methodological approaches to understanding the influence of artifacts on cognitive work, I relied on taking photographs of the artifacts, coupled with in situ observations of their use, as well as questioning the clinical staff about them in interviews. I studied the artifacts with an eye to understanding the role they played in coordinating and channeling the information flow and the influence that this flow had on the cognitive activities they intended to support.

Over the course of my observations, I was surprised at the role that cognitive artifacts played in the ICU. Contrary to what I expected, artifacts were involved only very little in the high-level work of decision-making (i.e., reasoning about causes and consequences, prognoses, alternative therapies; Knauff & Wolf, 2010). Rather, I observed that, for the most part, the cognitive artifacts were designed to support low-level aspects of cognitive work (memory, attention) and the administration of medical care. The artifacts that were

involved in high-level cognitive work were often ineffective and "*more of a nuisance than anything else*" (Consultant # 4; this included the electronic decision-support, as well as the communicating complex information through the chart-based progress notes). Still, even though cognitive artifacts in the ICU were generally not designed to support high-level cognition, I sought to better understand the influence they had on it. To that end, I directed my attention to the flow of information across artifacts, the content of the artifacts, the way information was represented and organized, and the intended and actual use of information. I was interested in those artifacts that were primarily intended to support clinical work, rather than administrative or organizational purposes.

Participant type and number	Participant experience and other details
Nurse # 1	Senior nurse (female), over 25 years of practice
Nurse # 2	Nurse (female) with 10 years of practice, previous experience working in ICU in the United States; was an nursing informatics liaison
Nurse # 3	Senior nurse (female) with over 25 years of practice, decade of experience teaching nursing in developing countries
Nurse # 4	Senior nurse (female) with over 25 years of experience; works as a charge nurse
Nurse # 5	Nurse (female) with 10 year of practice
Nurse # 6	Bedside nurse (female)
Nurse # 7	Bedside nurse (female)
Nurse # 8	Nurse (female) with over 25 years of practice
Nurse # 9	Nurse practitioner (female)
Consultant # 1	Palliative care physician (female)
Consultant # 2	Senior Intensivist (male)
Consultant # 3	Physician who had dual training in critical care and surgical medicine (male)
Consultant # 4	Senior Intensivist (male)
Consultant # 5	Intensivist (male)
Consultant # 6	Surgeon (male)
Consultant # 7	Junior Intensivist (male)
Resident # 1	Surgical resident (male) on rotation in the ICU
Resident # 2	Surgical resident (male) on rotation in the ICU
Resident # 3	Surgical resident (male) on rotation in the ICU
Resident # 4	Surgical resident (male) on rotation in the ICU
Fellow # 1	Surgical Fellow (male)
Fellow # 2	Fellow with training in both surgery and intensive care, with international experience (male)
Fellow # 3	Fellow in intensive care (male)
Fellow # 4	Fellow in intensive care (male) with international experience

Table 1. Demographic information of participants whose data was included in the dissertation

Data Analysis Using Modified Grounded Theory

Ethnographic methods for data collection are highly compatible with a grounded theory approach to data analysis (Pettigrew, 2000). In this research I employed a modified grounded theory approach, which draws on the data analysis tools of grounded theory without the attempt to reach theoretical saturation or build theory. I coded participant observations and interviews as I collected them, using Excel to support my analyses. During open coding, I identified a range of possible codes to identify the themes. Once data was coded, I began axial coding, attempting to establish dimensions and relationships among the codes, and reduce them. For example, the code of 'hypothesis testing' included dimensions of who was involved in the hypothesis-testing (e.g., physician, resident), what they were using to help support hypothesis testing (e. g., communication technologies, chart, historical notes) and what precipitated instances of hypothesis-testing (e. g., low lab test value, pallid colour, resistance to intervention). After axial coding, I constantly compared the series of codes and categories with one another, and sought to reduce the data, identify the main categories. Concurrent with this process of data reduction and constant comparison, I sought to use my emerging categories as lenses through which to re-assess my raw data, and with them, I theoretically sampled the data in order to more fully develop the emerging categories.

My analyses were organized around episodes of clinical decision-making. During these episodes, as physicians were confronted with clinical problems or questions, they would seek to organize the resources available to them in order to produce a decision outcome. Sometimes a decision could be reached within a few moments – after a check of the chart, or phone call to a colleague, while other times, decisions would take several days, emerging only after information from many independent resources were collected, organized and contemplated. I was interested in how all kinds of decisions emerged, what

steps physicians needed to take to get the information needed, and use it effectively to serve a decision purpose.

I entered the research field without a preconceived idea of what I should be looking at, but with general sensitizing concepts that directed my observations (Bowen, 2008). I began my analysis with a conviction that decision-making was accomplished through the cooperation between social, technological and material agencies, and so I regularly sought out the immediate context that made decision outcomes possible. For example, when I observed some aspect of decision-making, I would take note of the documents used by practitioners, how and when they were used, and whether they were part of the teams' regular practice or not.

I sought to ensure that the data analysis was rigorous, credible, and transferrable. To these ends, I utilized several mechanisms suggested by qualitative researchers. Credible research is believable to the reader, and inspires a sense that the researcher has accurately recorded the phenomenon under scrutiny (Shenton, 2004). To ensure credibility, I prolonged my involvement in the research setting, and developed an intimate familiarity with the culture of the ICU (Guba & Lincoln, 1989; Tracy, 2010). This helped me to avoid simplistic interpretations of local phenomena. It also enabled me to build strong bonds of trust with the research participants, and allowed me to gather information that I would otherwise not be privy to. Secondly, I sought out examples of outliers, exceptions, or negative cases to the phenomena of interest (Miles & Huberman, 1994). For example, when observing the use of information resources in the standard ICU admission process, I sought out exceptions to how the resources were used, who used them, and when they did not fulfill their intended purposes. Thirdly, I strengthen the overall data collection and analysis by relying upon triangulation. I would seek corroborating evidence from different sources: interviews, observations and artifact analysis. When I observed an episode of decision-making I would inquire about it with several research participants independently, trying to compare and integrate their perspectives into an overall account (Bloor, 2001; Denzin, 1978).

I also sought to ensure transferability of my findings (Guba & Lincoln, 1989). In qualitative research, transferability implies that research findings are useful outside of the context where they were collected. It requires the researcher to make effort to render the circumstances of data collection, and the steps of data analysis clear to the reader. This entailed using several techniques: Firstly, my goal was to provide 'thick description' both of the research environment, information resources and process, and culture of the ICU. Beyond this, I also wanted provide abundant demonstration and illustration of the research design, its implementation, the operational details of data collection, and my efforts at critical reflexivity (Tracy, 2010; Shenton, 2004). I kept an audit of the research by retaining organized records of the raw data, the data reduction process, personal notes, and the instruments developed for the research (Lincoln & Guba, 1985). I engaged regularly in reflexive journaling, always seeking to understand how my own subjectivity influenced the collection and analysis of data (Tracy, 2010; Shenton, 2004).

The methodology of cognitive ethnography, and the focus on clinical episodes will allow me to see how people, paper, and technologies come together to support the emergence of medical decisions. In the next section I describe my findings, highlighting specifically the interactions among information resources, how they influence the ability to make decisions, and what systemic consequences arise from them.

Chapter 4 Findings

In my findings, I seek to explore and articulate the misalignment that exists in the ICU between the system of information resources designed to support static, predictable, linear and individualistic decision-making in the ICU, and the dynamic, multifaceted, unpredictable, and collaborative needs of medical decision-making. Instead of looking at decision-making in terms of what a lone physician does with information to make a single choice, I follow the systemic preparation of information resources throughout the ICU, how information is used in decision episodes, and the way that physicians respond to the information made available in the ICU. To describe the process of decision-making at this level of analysis, I illustrate the challenges to decision-making in the context of three distinct yet interconnected cognitive routines: assessment, monitoring, and planning – without trying to expunge all the overlap that occurs among them in daily life (Choo, 2006; Jenicek, 2013).

At this level of analysis I was able to investigate the emergence of decisions as a whole process that result from interactions and relationships among information resources of the activity system (i.e., the clinical staff, chart, EMR). I demonstrate where and how the information resources are designed with too narrow a view of doctor's decision-making needs, and the cognitive and workflow consequences that follow from it. These misalignments among the information resources lead to consequences that unfold as unintended ripple effects that often go unobserved elsewhere in the activity system (Patel et al. 2008). Having to cope with these misalignments (and the consequences that follow from them), I noticed how doctors engaged in compensatory strategies to overcome the limitations of information resources, satisfy their complex and dynamic information needs, while simultaneously mitigating the negative the negative consequences arising from them. With data drawn from ethnographic field notes, excerpts from interviews, and photographs/graphical representations, I illustrate the difficulties associated with making decisions in a modern ICU environment, highlighting where physicians interact with the material, technological, social information in order to make decisions. Before surveying

my findings, I give a brief overview of the ICU context, and the scope of the information resources that make up the activity system for ICU decision-making.

Overview of the Field Site and Activity System for Decision Making

The 16-bed ICU specialized in patients who were recovering from various forms of cardiac surgery (CABGs[2], TAVIs[3], and other heart procedures.). As a result the patient population was more specific and less complex than what one usually finds in traditional general-service ICUs (i.e., less variety of diseases, fewer comorbidities, etc…). Aside from the approximately one dozen consultant intensivists who were in charge of daily aspects of patient care on the ward, it had one full-time nurse practitioner, approximately 200 nurses, a full-time pharmacist, nutritionist, and a stream of rotating fellows (i.e., physicians who had completed residency training) and residents (i.e., physicians currently enrolled in residency training) fulfilling their training requirements in cardiology, critical care medicine, anesthesia and internal medicine. Not untypical of many medical settings, the training requirements of medical students, residents and fellows, and the need of the staff (nurses, nurse practitioners, consultants) to train them resulted in a stratified culture, where nurses and consultants had generally stable expectations of one another, and knew how to practice with one another, the medical staff in training was always getting used to 'the way things are done around here', on top of their responsibilities in learning the content associated with their rotation.

The ward was an open unit, rather than a closed one, which means that the intensivists on the ward shared responsibility of patient care with an acting surgeons, of whom there were approximately 10. The need to negotiate patient care between the intensivist and surgeons was, at times, a source of tension. Although there was a formal account of who the MRP (i.e., the physician who holds final decision-making authority) was in which case, this was not fool-proof, and the responsibility of the physicians was sometimes ambiguous.

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[2] Coronary Artery Bypass Graft, a common heart surgery used to restore normal blood flow to an obstructed coronary artery

[3] Transcatheter Aortic Valve Implantation, a less common procedure where an artificial aortic valve is implanted to replace a diseased one

The ICU had a regular daily rhythm. At 6:30am, the surgical team would round on the patients to determine whether they were ready for discharge. At 8:30am, the daytime intensivist would arrive and morning rounds would proceed. These usually consisted of 8-12 people, including the overnight resident or fellow handing the care of patients over to the consultant, 2-5 residents, the nurse practitioner, pharmacist, and charge nurse. Following rounds was several hours of unstructured time, where the residents would familiarize themselves with their patients, do their charting, and communicate with the consultant about difficult issues. In the early afternoon (somewhere noon-3pm), after the care team was brought up to speed on the patient's active issues and the plans of care were formulated, the consultant would take the opportunity to teach the residents and fellows about current issues in critical care and cardiac surgery. After teaching, came afternoon rounds at 3:30pm, after which the majority of the ICU staff went home. Patient care was in the hands of a consultant, one overnight resident or fellow, and a charge nurse, and the ICU would slow down. In general, if there were no new patient admissions or medical issues to be actively managed the consultants would often read or engage in research. At around 9pm, the consultant, overnight resident and charge nurse would round one last time on the patients, anticipating the course of the evening, and checking their plan. After 9pm the consultant generally went home and the resident was left alone to care for the patient.

The ICU was physically arranged as one might expect a North American hospital to be: long, broad corridors where one would find patient rooms divided by curtains. The ICU beds stretched out along three such corridors, with a large desk and room at its center (See figure 2). Each chair at the desk and in the room was placed in front of a desktop computer, where physicians, pharmacists, residents and charge nurses could sit to access the EMR, internet, or hospital resources. At each patient's bedside was a nurse, and a bedside workstation – a computer that where the bedside nurse could access the EMR. On top of the workstation was the patient chart and the nurses' flowsheets (See figure 2).
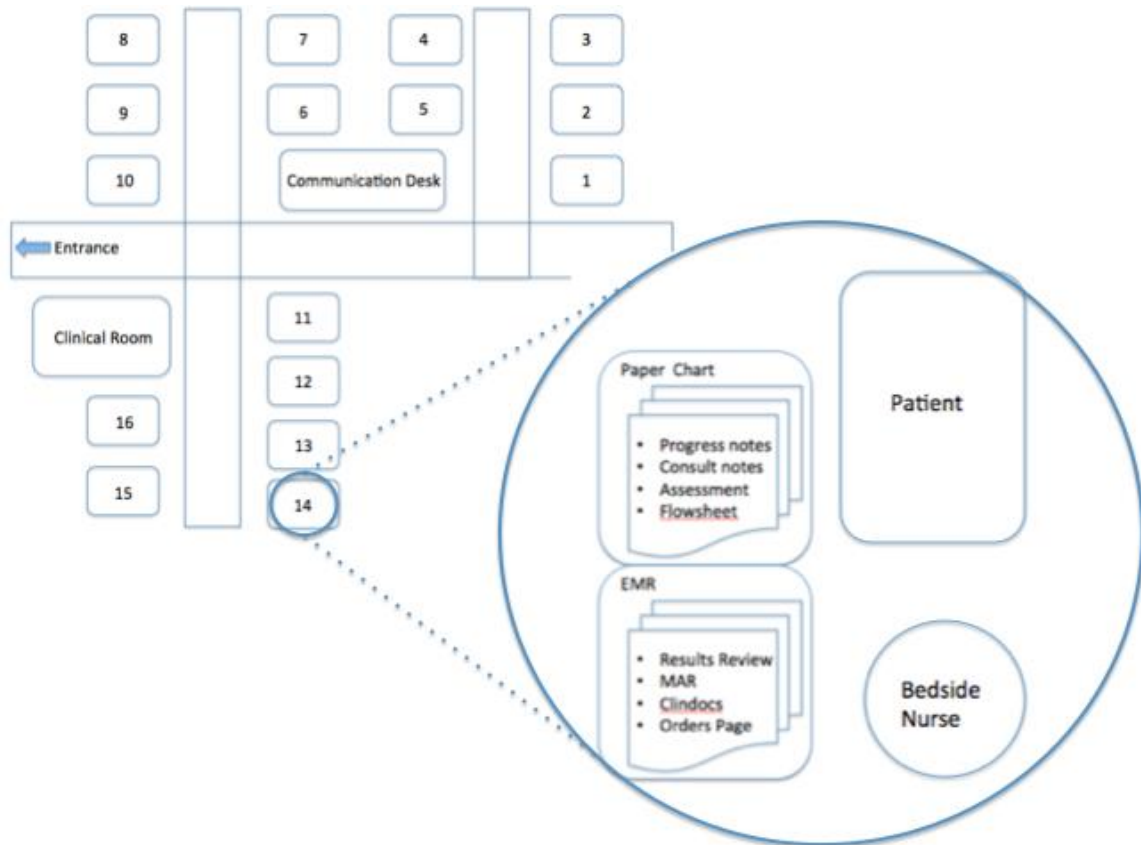
Figure 2. Physical layout of information resources as a single bed in the context of the whole ICU

On the whole, the formal information resources that were used in the activity system of ICU decision making were the results review page, the MAR, the orders page, clindocs browser system, the nursing assessment, nursing flowsheet, progress notes, and the ICU admission note (See Table 2 for a detailed description). Each of these information resources served a distinct purpose (both intended and unintended), had a particular origin (some being developed endogenously and other exogenously), held different pieces of information, presented information in a different way (e.g., textual, numerical), and different sources and methods of being updated. Aside from these resources, some of the members of the clinical staff had an active part in ICU decision-making, including the consultants, nurses, fellows, residents, and pharmacists.

Artifacts	Information

EMR
   o Results Review
   o MAR
   o Orders page
   o Clindocs (Clinical History)
	Results Review: A single page consisting of cells that lists the values of various blood tests and lab work. Includes, for example, blood chemistry, point of care bloodwork, hematology, and coagulation factors.
	
	MAR is a chronological, workflow centric presentation of the medications (which form, dosage, timing, etc..) and medical interventions to be given by the nurse.
	
	Orders page contains the same information as the MAR, but it is presented as an alphabetical list, rather than in a chronological, workflow-centric way.
	
	Clindocs is a system to organize and present text files that detail the patients historical notes:
	   • Previous provider assessments
	   • Daily progress notes
	   • Summarizing comprehensive notes

Nursing Assessment	Comprehensive assessment of the whole patient. Neurological, respiratory, Cardiovascular-hemodynamic, intravenous, Gastrointestinal, Genitourinary, Charting record of nursing interventions (Star & Dar format or narrative format)

12-hr Nursing Flowsheet	Record of nursing interventions made (e.g., position, chest care, oral care, bowel care, respiratory, restraints, dressings, suctioning, etc…)
	
	Fluid balance
	
	Vital signs record
	   • Blood pressure
	   • Heart rate

Patient Chart
   o CSRU admission Note
   o Patient progress notes
	The CSRU Admission Note contains
	   o Historical details: Cardiac risk factors, meds, allergies, pre-op investigations,
	   o Surgery details: procedure, pump time, clamp time, pressors, heparin, protamine,
	   o Physical assessment: CNS, settings of the respiratory support system, GI, GU

Table 2: List of information artifacts in the ICU activity system

In what follows, I describe ICU decision-making in terms of three interconnected routines: assessment, monitoring, and planning. Assessment involves getting the picture of the patient, understanding the parameters of the problem(s) being treated, monitoring involves updating one's understanding of patient as they convalesce, and planning involves formulating a strategy about what medical steps to take in order to assist the

patient's convalescence. These steps are not sequential and linear, but proceed in a nonlinear way. In my findings, I highlight the systemic difficulties that arise as a result of information resources that are not suited to the dynamic, collaborative, and multifaceted decision needs of physicians.

Assessment

When a patient is admitted, the clinical team starts by establishing a comprehensive picture of the patient's status. The main cognitive task in assessment is for the physician to get a "*360° understanding of the patient*" (Fellow # 2), ensuring that nothing relevant to the patients care gets missed or misunderstood. Assessment lays out the parameters for patient care, and sets the expectations of the clinical team to patient's likely post-operative course. This involves a process of scanning through available information to find all the elements that are relevant to ICU care: the patient's medical history, chronic diseases, current medication list, recent medical history, surgical procedure, and the minute medically relevant events of the last 12 hours. The physicians will be interested in the physiological status of the patient (e.g., kidney, heart, and liver function), level of consciousness, urine output, and how the patients' disease and comorbidity status may influence their course.

The major source of information for assessment is handoff from the surgeon and anesthesiologist (see figure 3). Handoff (where a patient's care is transferred from one attending physician to another) is a standard routine in the ICU. It is highly developed and informative. In this structured oral account, the surgeon gives a summary of the patients history and presenting illness, the procedure that they underwent to treat that illness, how the procedure went, their medication list, and the active post-operative issues that they expect the intensivist will have to deal with (e.g., management of patient bleeding, unstable blood pressure, etc…). The opportunity for two physicians responsible for the care of a patient to come into direct contact with one another is very valuable. More than simply giving the details of the surgical procedure, as one would get from the EHR or from a note, the transferring physician, being a storehouse of rich expertise about

the patient, is providing the ICU physician with a mental model, which includes the important parameters of patient care: the active issues, their causes, complicating factors, untypical presentations, and modes of treatment. Because the information is from an expert in the field, what is said is also as important as what is left unsaid.
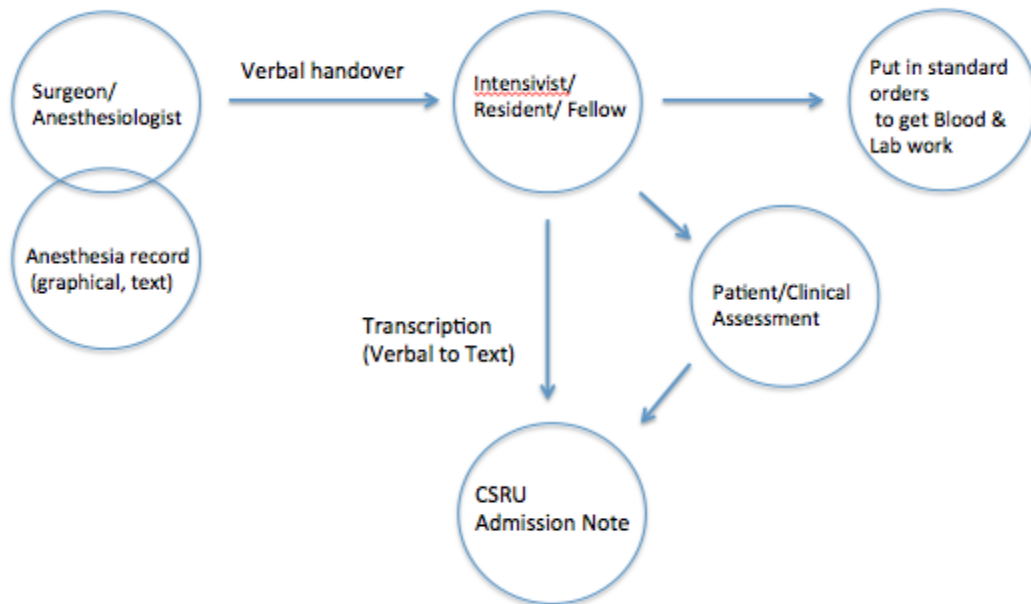
Figure 3. Resource Map for ICU Admission and Handoff.

It is highly relevant that handoff is done face to face between two or more attending physicians. Face to face interaction, particularly between experts, is among the most dynamic, informative sources of information available in the ICU. As one fellow said *"the best by far is face to face. Certain people are effective with written communication but they're in the minority"* (Fellow # 3). Similarly, a surgeon told me *"we communicate face to face as much as possible"* (Consultant #1), while a senior nurse affirmed that "*if there is no face to face, its troublesome. We look for a face to face communication"* (Nurse # 1). According to Coiera (2000), a major advantage of face-to-face communication (and other means of unstructured communication) is that it is open, and allows practitioners to establish *just in time* common ground for decision-making. This allows practitioners to engage in a dynamic and flexible conversation, sharing only those pieces of information that are directly relevant to the problem at hand. Furthermore,

because the surgeon and intensivist share general expertise, the surgeon is able to judge what may be of interest to the intensivist for the immediate post-operative period and give contextual information accordingly. As a result, the surgeon can convey a focused picture of the patient's state, condensing lots of multilayered, multifaceted information in a brief account.
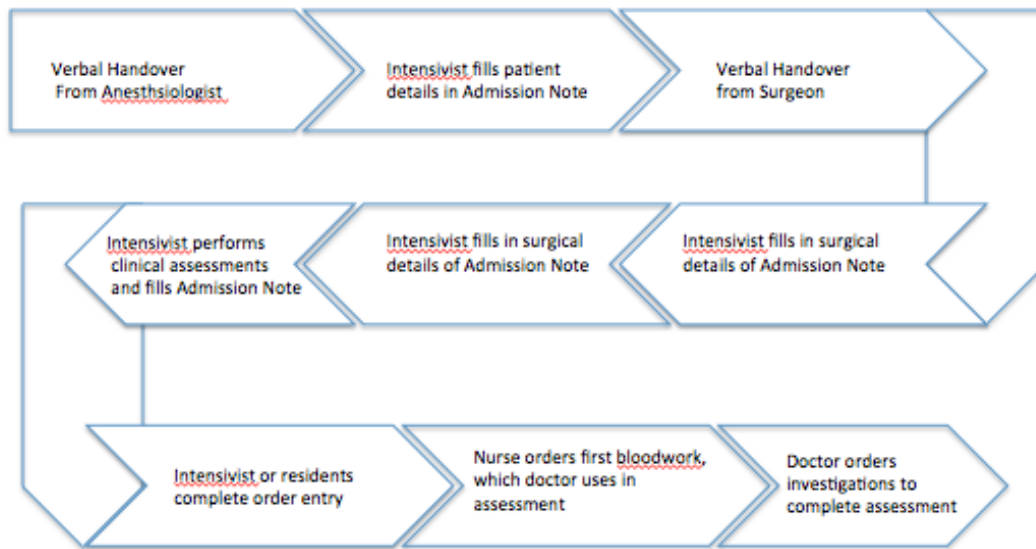
Figure 4. Overall depiction of the information flow associated with Handoff.

<u>*Difficulties assessing the patient with formal information resources*</u>

As rich as handoff is as a communication channel, it is easy to miss, and when missed, the information transferred by it is generally not possible to reproduce in the same way. During busy times in the ICU, there were often several patients being admitted simultaneously, and as this is the case, the clinical team would split up, each one receiving handoff from the surgeon. Hence, while the face-to-face approach of delivering handoff is rich from the standpoint of information quality and relevance, it is costly, easy to miss and difficult to reproduce (Parker & Coiera, 2000; Coiera, 2000). When handover is missed, the ICU physicians will often resort to sifting through the formal information resources about the patient – that is, the patient chart, the EMR, and bloodwork (See table 2 for a comprehensive list and brief description of ICU information resources), and this will have a detrimental effect on their ability to understand the patient:

"If the patient is transferred in from the periphery [i.e., the hospitals outside of the major urban center], we struggle to determine why they're here and what happened. If there is no paper trail, we go to the computer and hope that they've been in this hospital system before, but often they have not been…. So, that's one we're faced with often. If its at night you'll wait 12 hours to retrieve reports, and you work with what you have – word of mouth, try to get a hold of a physician at the site, and so you have to work with assumptions. Me: So you can't direct your interventions, you just keep them alive and then you hunt…*F: Pretty much it, …that type of thing happens quite a bit, where you're given some info, you know the gist of what's going on and so you kind of scramble to stabilize, figure things out quickly, and then once you have some realm of stability, we'll go to paint the picture, background history and all that"* (Fellow # 1)

Low Resolution information and lack of support for seeing the 'big picture'

Beyond the problem of missing information, which is what the fellow in the quote above is referring to, there is also the problem of how the information that is not missing is presented. To assess a patient, physicians need a complete survey of the patient's information, so that they are aware of all the characteristics that are of actual or potential importance to the care they will provide in the ICU. This means that physicians need support in seeing the big picture of care - the whole landscape in a single view, yet getting this comprehensive view is very difficult in the absence of handoff. Physicians intuitively understand this need, and provide the details of care in the context of the high-level, bird's-eye view assessment. Yet physicians struggle when they need to get this type of multifaceted information from the EMR.

To illustrate, I observed a fellow doing an admission when he[4] did not have access to the routine verbal handoff. As a result, he needed to simultaneously familiarize himself with the patient details, while he stabilized the patient and administered care. Balancing the two tasks, his understanding of the patient growing, he noticed that the patient had

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[4] In illustrating actual observations from my data, I use the first and third person singular pronouns associated with the gender of the participant being referred to.

recently been prescribed Apixaban, a drug whose presence was inexplicable, given what he knew of the patient. Another historical document revealed that the patient had a metastatic melanoma, which, in the words of the fellow "*can change everything*" (Fellow # 2) in his patient management. As a result of these two findings, and with no other information resources to turn to, the intensivist was forced to sequester himself to study the patient's clindocs pages more closely, specifically looking for reasons that would explain the indication of the Apixaban drug and the mention of metastatic melanoma. For almost twenty minutes the fellow opened, visually scanned, and closed dozens of EHR reports (a search function not being available) from the referring cardiologists and oncologist, diagnostic imaging and other records. He concluded that "*most of the orders which the patient was admitted with were wrong*" (Fellow # 2). In connection to the importance of a high-quality handoff to give the admitting physician an initial assessment, the fellow said:

> "*...the main problem in cardiac surgery...is the flow of information. So the patient came by, is admitted and then past medical history should be recorded along with current, open and active issues....you shouldn't really spend a lot of time going through past medical history, asking the patient and going through tons of notes. Cardiac surgery is a subspeciality so someone else should filter it... So if the patient arrives they should arrive with a complete history and completely screened – you shouldn't need to go here and there, or phone the referring physician or hospital.*" (Fellow # 2)

Because of the range of factors that physicians will be interested in and the nuance with which they think, building the picture of care can be complicated, involving many questions, comparisons, judgments and interpolations. Physicians in this scenario must work to find, access and compile the relevant pieces of information, comparing each of them to the overall picture of care in order to determine their meaning. As illustrated in the scenario above, physicians who use the information resources to do this have little support for this process of aggregating single pieces of information into a coherent whole or comparing distinct observations in the emerging picture of care. Hence building the

picture of care can place onerous demands on working memory, and inhibit a physician's ability to abstract away from inessentials, and reason at a high level.

Disorganized resources and undue navigation

A good handoff can give you a complex, comprehensive, and high-level picture of the patient relatively easily, but if you need to build that comprehensive picture of care without the handoff, without a seasoned expert to provide the parameters of your investigation, it can take a lot of undue searching, digging, and 'fishing'. Specifically, in the example above, given the particular finding of Apixaban, the details necessary to build a complete picture of its relevance were strewn across several documents in the historical feature of the EMR system. Sifting through those notes was made more difficult because of the absence of a feature to organize the documents themselves along clear parameters. Many residents and fellows I spoke to expressed frustration at the extra work involved in thinking about care within the constraints of the formal information resources:

> *"..sometimes there's nothing on here (clindocs) that helps me. This is their past medical history, so depending on what types of questions I'm trying to answer its important to quantify the degree to which their existing comorbidities are influencing this particular admission. That might mean I have to dig deep – so if I find a clue in one note, I might have to follow it back. For example, if I see one note by this radiation oncologist, and what happens a lot is that they allude to a previous note in their current note. So then you go fishing through 5 or 6 of them…"* (Resident # 3)

> *"...they [the patients] come with a big stack of papers and in there somewhere is an investigation that is very important, and its not organized.…When things are not presented to me in a way that I'm used to, it's very challenging for me, and my cognitive load goes way up. Cause now you're thinking about – what could I be missing? When it is presented to me in a familiar way, it's a game-changer,*

because I know that I'm going to catch everything that has been done. And I have an idea of what hasn't been done – just by the way it looks." (Resident # 2)

"...if you can't find things in the right place, then you have to search, and this takes time ... imagine you have papers in the wrong place and the patient is unstable. Its all in separate parts – the paper notes, all the hospital information will be in the paper form. And if the patient is here for four months its difficult to have the chart to keep growing, so you'll trim it, and then it goes in a separate folder, and then you have an extra source of information. So its more time consuming and more difficult, sometimes you don't find the papers in the right time, because you don't even know if that paper even exists. You don't know what you're looking for..." (Fellow # 4)

Searching through the clinical notes for patient assessment was difficult, since, beyond having no search function, there was no way to determine what is inside the note by simply glancing at it. As a result physicians had to enter and exit several notes before finding a promising one. Kirsh (2001) argues that cognitively congenial work environments make use of *entry points* – cues that signal an invitation to enter an information space, and give some indication about what might be found there. In this case, physicians often expressed their frustration using the clinical history function because the entry point of the patients clinical history were poorly displayed, and all types of clinical documents displayed the same types entry points. As a result of the poorly displayed entry points, many of the notes the physician selected were not comprehensive notes, but daily progress notes, which are about isolated incidents in the patients care, rather than comprehensive summaries. Associated with the lack entry points that clarify the content of the information on its surface is the unclear entry protocols to add historical notes in the EMR, which makes it so that any practitioner at any time can input new historical documents. The consequence of this feature is described eloquently by one of the surgical residents:

"...the advantage of the EMR is that you no longer have to go to the chart to find the history, and you don't have to rely on the patient either. But the more we put on there, the more challenging it becomes to sift through a lot of the repetition and garbage to get to the key things." (Resident # 2)

To summarize, physicians rely on high quality information in order to assess patients. Usually, when another physician gives handover, they get highly integrated and multifaceted insights organized at several levels of abstraction simultaneously. They can ask pointed questions about the patient and receive direct, contextually sensitive answers. Yet when physicians are forced to rely on the formal information resources to build a comprehensive patient assessment, they struggle to abstract away from the inessentials and have difficulty navigating available information. As a result patient assessment becomes unduly complicated. To better support the physician in forming a patient assessment, the formal information resources must encode more diverse, expressive and integrated forms of information, and better support the physician's navigation through those resources. In the next section, I deepen the study of the information resources in the context of patient monitoring.

Monitoring

In connection with monitoring the patient, the physicians need to be sensitive to indicators that communicate things to them about the patients, which may not have been part of the formal handoff process. Whether these were omitted by the transferring physician, or are new developments in the patient's condition, physicians need nonetheless to be aware of new developments, and understand their significance. Some aspects of the patients' condition are easy to detect and understand – often they are expected in the trajectory of recovery, or are directly and conclusively indicated through objective clinical markers, such as a high hemoglobin indicating high blood flow. Other times, developments in the patient's course are not easy to discern or understand. They will require looking at an array of indicators in conjunction with one another, understanding complex patterns of cause and effect, or seeing things from multiple perspectives simultaneously to witness a whole pattern.

Monitoring the patient was done through three information processes:

1. Firstly, the doctor will rely on the bedside nurse to alert him to anything out of the ordinary and will regularly solicit updates.
2. Secondly, the doctor will rely on the nurse's charting of physiological parameters or on regularly ordered blood work as it appears on the results review page.
3. Thirdly, the doctor will rely on the daily progress notes prepared every afternoon by the resident or medical student.

In each of these cases, the information encoded represents some aspects of the patient well, but not others, which presents particular difficulties to the overall process of collecting and using information for decision-making. In figure 5 below, I provide an overview of the interactions among the information resources that make patient monitoring possible. The extent to which these provide comprehensive, multifaceted, nuanced and dynamic information to the consultant is the extent to which the activity system for ICU decision-making is well-coordinated and well-aligned. However, as we will see, there are several instances where information does not fit the decision needs it intends to serve, and this causes unintended consequences both within the activity system and beyond.
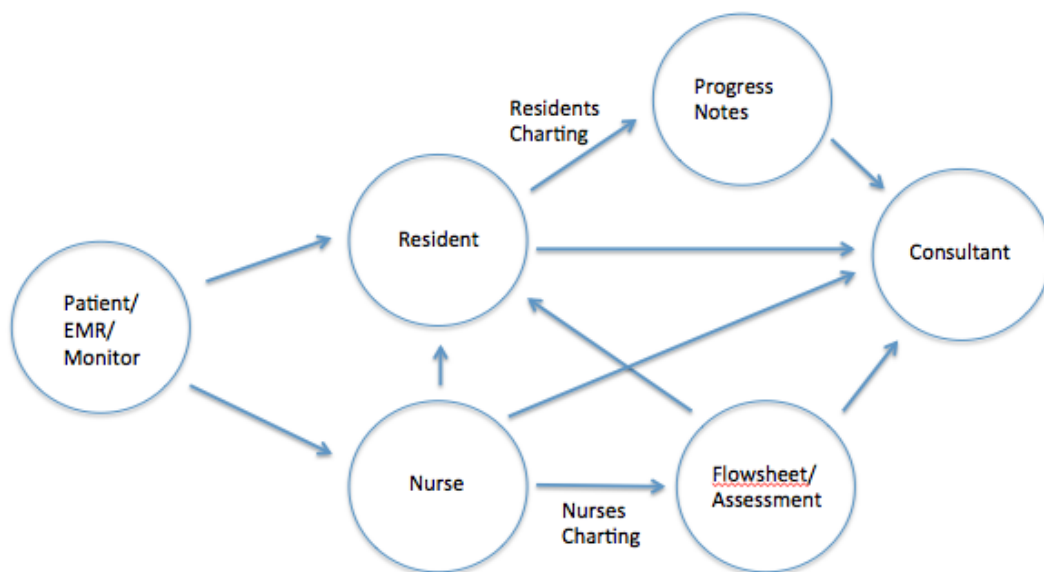

Figure 5. Resource map showing the main information resources and relationships in monitoring

Firstly, the nurses are the 'eyes at the bedside'. They are charged with keeping track of a number of clinical markers, and alerting the physician or fellow if anything is out of the ordinary.

> C: "We rely a lot on others and on technology to alert us about that. If there is something that is grossly out of the norm, we rely on others to alert us to that…" (Consultant # 2)

> "Me: So the doctors don't need to know the clinical details to direct the big picture? *Not really. They think more it in terms of big-picture, rather than smaller details…*" (Resident # 4)

Still, the strategy of relying on the nurses and their charting for a sense of the patient's ongoing issues can be problematic. One fellow mentioned that the implicit trust that a nurse would alert a doctor of an anomalous event was not always founded:

> "Every nurse has a different threshold to keep the physician updated. There is a matter that sometimes you realize after a few hours that the patient bled more than you expected. So because we have different clinical judgment we shouldn't have to trust others…it should be an automatic system." (Fellow # 2)

This is important especially in light of the fact that research has shown that physicians base their assessment of the relevance and validity of information primarily on the trustworthiness of its source (Sweenen et al., 2013). Trust is a vital component of the process of information gathering and use, and if a physician did not trust a nurse's judgment, then they would often have to reorganize their information gathering processes to rely instead on a source they did trust. This process of relying on the nurse to provide updates about the patient also became more complicated as the elements being monitored were more subjective, or more dependent on expertise to detect. As a result, many

doctors relied on the principle to check things for themselves, and not depend on the judgment of others:

> *"A lot of the information is presented to you through an agenda… a lot of the data is collected by people who are not me and then presented to me. So there are objective things to measure like outputs (urine and chest tube), so the number is the number, and then other things have elements of subjectivity, like GCS (a measure of neurological status) is mostly objective but sometimes not, or "obeys commands", or "is neurologically intact", or "moves all four limbs", or "is agitated" – what does that mean? Does that mean "please give the patient an atavan so I can go back to reading my book?" or does it mean "he's going to pull open his sternum, please come help him?" So one of the things I do to mitigate that is get as much of the info I can myself."* (Resident # 4)

A second source of information for monitoring consisted of the nursing assessment and flowsheet documents that nurses kept (See Appendices 6 and 7, respectively). Nurses record details about the hemodynamics, vital signs, ventilation, temperature, nutrition, and metabolism, including the timing and dosage of medications or other interventions, fluid intake and output, chest tube drainage, and a variety of other physiological and clinical parameters of importance. This charting is labor-intensive. In the words of one senior nurse:

> *"It takes a lot of time to write all of this, and what we have to write here [in the flowsheet] we also have to write there [in the assessment sheet]. To me it takes away from patient care. It's bogging us down with the wrong priorities….I just think that its asking me to write down every single time I glance in my patients direction."* (Nurse # 3)

Another nurse told me that

"I think in Canada we are so used to being in control of every aspect of the patient that they don't want to give up any aspect of it. And it is going to get harder because people are getting sicker, and hospitals are trying to get by with less staff. So its very difficult. [In the United States] even in the most acute situation we record the vitals every two hours – whereas here even if the patient's been here for months we are still recording their vitals every hour! Which is time consuming, and you could be in the room with the patient…" (Nurse # 2)

Many were of the opinion that these intense charting requirements did not support care but rather distracting the nursing staff from actual needs of patients. In the words of one senior nurse:

"*I would say that people are lying if they don't think the standard of care has gone downhill. As we've become more technical, basic care has gone down. We're not staffing to what we should, classically we would always turn our patient every 2 hours, but not anymore. I'm not talking about the life-saving things, but the little things we don't do anymore. We are spread so far out because we don't have the resources, or we're always on the computer or charting*" (Nurse # 4)

The third source of information that was regularly created and used for monitoring purposes was the daily progress note that residents and medical students would create and place into the chart. Every morning after rounds, residents, fellow and medical students would divide the patients in the ICU and chart their progress in the last 24 hours. To do so, they would bring the patient chart and open it at a desktop computer in order to look at results review page, progress notes from previous days, and clinical history all in one glance. They would provide a basic written update about the patient's status and progress in their recovery (most of the time a paragraph or two).

Charting the daily progress notes in the ICU is an institution of the craft – medical students learn how to do it, expect to do it, know what information is relevant to it and

what is not. Still, the medical note suffers from problems similar to those that beset the nurses clinical note. Having discussed this at length with many practitioners, one statement that stood out to me for its candour was when a fellow told me: "*Certain people are effective with written communication but they're in the minority – a lot of time the note is just a rehash of what was said…." (Fellow # 3)*. Without undermining the legitimate value of the progress note, there was still a sense of cynicism among some of the physicians that the information in the note less useful when physicians were trying to generate insights or refine or narrow the possibilities of their hypotheses or clinical investigations. In a word, it didn't support a clinician's clinical intuition, or foster the development of incipient insights because the formalized expectations around its structure and the underlying assumption of objectivism that it imported served to render the progress note sterile and uninformative. In what follows I develop these insights and their consequences in the context of showing the interactions among information resources that are used to support patient monitoring.

Difficulties using information resources for patient monitoring
While the information collected across these three resources (i. e., nurse, nurses charting, residents charting) was highly valuable, it was characterized by problems that rendered it difficult to use in decision-making. Overall the information resources available for monitoring were too detail-oriented, characterized by an unnecessary penchant towards objective numbers. They also tended to be disjointed and fragmented, dispersed across platforms that were physically distant and representationally misaligned with the decision needs of the physicians. The ultimate consequence of this was to produce information and cognitive overload for the physicians (See figure 6 below for a visual of the main argument).
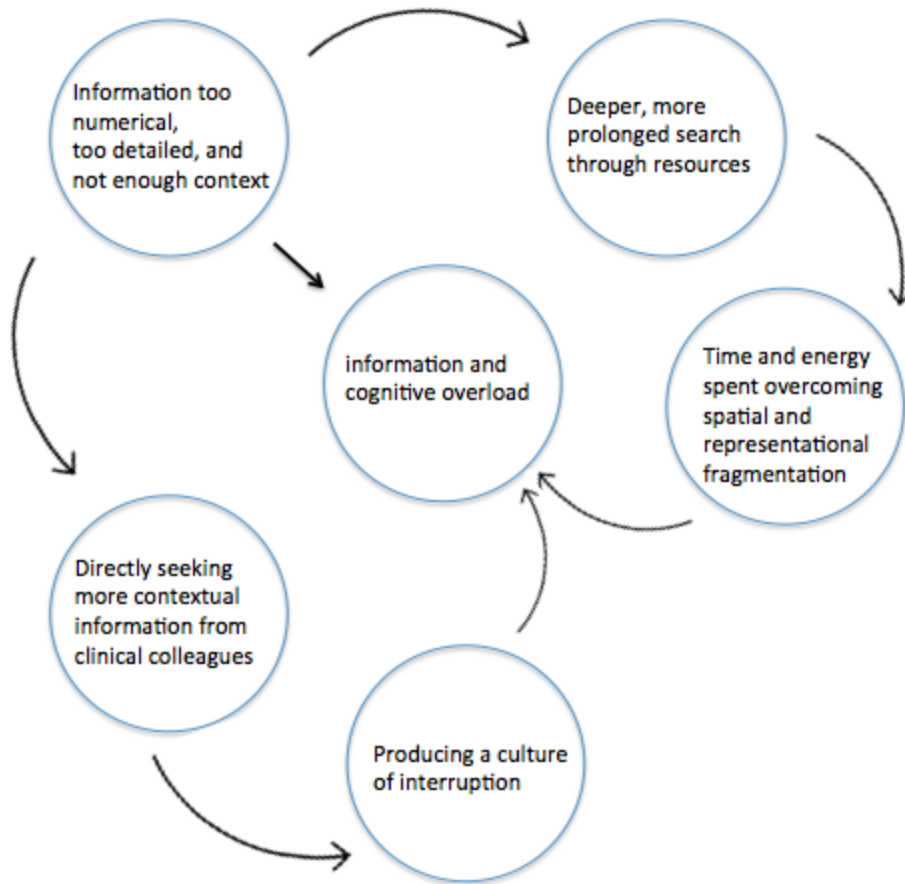
Figure 6. Visual of the system of interacting conditions that produce information overload in monitoring

Information too discrete and numerical

One particular problem associated with monitoring was the lack of information resources that display the trend in clinical markers, and overemphasized discrete numerical details. As one senior physician told me, for many purposes in the ICU the numerical details of the heart rate and blood pressure did not really matter. Rather, the important issue was the relative change over time – a trend. This was the case, for example, where physicians would be interested in the current heart rate and blood pressure in the context of the trend in those values over time.

> *"The reason why the ICU exists is that all these pieces of info can be provided at the same time. Because you have advanced monitoring systems and a fully monitored bed, but if you look at the monitor sometimes you can't just read*

numbers, you have to spend some time watching because you need a trend. If you
recorded the trend on the paper chart you don't have a real trend – you have a
number at the time, not a trend. And for one reason or another if a patient is at
80, it gets recorded at 80, but if you see a trend that 80 is not significant; when
the pressure has been consistently over 100, for example." (Fellow # 2)

Hence, too strong a focus on the discrete, objective, quantitative details of patient
physiology sometimes did more to interfere with the tasks of patient monitoring. The
overly-objectivist bent of recorded information places on the physicians the need to strip
it of the inessentials, and retain what is purely informative. They need to work to omit
irrelevant details while retaining the essence (Patel, Kaufman & Kannampallil, 2013).

Associated with this, one physician explained to me that different physicians employ
different strategies to monitor patients. Some rely heavily on diagnostic imaging, while
others organize their thinking around the bedside assessment. Yet currently, and arguably
because of the wider trend within medical decision-making health and information
systems, the predominating direction of informatics support is geared towards numerical
reasoning:

"*You know, we love numbers in our data, and I think its' important, but it always*
has to be integrated with the patient, and that integration, I don't know how you
do that within our current electronic environment because we only look at one
aspect of the data – we only look what our blood work shows, but it doesn't speak
to our monitors, we can't integrate it into the clinical condition of our patients.
Even if you could, that's only one snapshot of it – the things you can measure in
numbers and send to the electronic record, right? And that would be hugely
informative, but it still wouldn't account for the fact that you need to see the
patient, put your hands on the patient, and interact with the patient, to fully
integrate what all that data means, Right? and that, even with a fully integrated
electronic record still won't include that component. Because there are times

where the numbers that you get are wrong or they don't paint the picture, and you don't know that until you see the patient." (Consultant # 4)

"*There are other aspects of patient information that aren't recorded anywhere now, but you keep them in your head – that includes the pre-test probability of what you think various things are in your differential, to the actual information that you get to sort out that differential hierarchy, and specifically an example would be – I pay very close example to clinical examination/ bedside assessment – how a patient feels, how they look, what is happening, other people rely heavily on imaging and ultrasound. We don't have the ability to have that information trended easily or immediately, so what we've done is ... we categorize our brains to remember what he looked like the last time I saw him. That was two hours ago. It would be nice to know what the one hour examination looked like, but there is no way for us to record and communicate that information.*" (Consultant # 3)

Clinical thinking is not only an exercise in numbers, and while the numerical information in the formal resources helps clinical thinking, it nonetheless offers an incomplete picture of the patient when not integrated with the whole picture of the patient. This is a misalignment between the information resources and the decision-needs of physicians. When physicians get information from their formal resources, they need to elaborate upon them to place them within the actual parameters of their clinical thinking. This includes gathering a variety of different types of information (image-based, graphical, visual pattern recognition, and tactile pattern recognition), trending it over a long period of time, and then expanding and extrapolating it to possible future scenarios.

To serve these decision needs, physicians regularly engage in a variety of activities that compensate for the misalignment between their information and their decision needs. For example, to collect more informative and contextually relevant information, physicians will engage in targeted searches through a wider range of the information resources – expanding their search for meaningful information into deeper recesses of the resources (e.g., clindocs, past progress notes, etc…). While a more engaged and prolonged search

through the information resources can be helpful in getting more relevant and contextual information, it can be time consuming, inadequate and sometimes carries with it a range of unintended consequences that ripple across the activity system and indirectly make clinical work harder. In the next section I address some added difficulties that physicians face in getting contextual and relevant information.

Two types of fragmentation – physically immobile and representationally static information resources

In their pursuit of meaningful, high-quality and contextual information, a major challenge that physicians face was the fragmentation that characterized the whole system of information resources in the ICU. While fundamentally fragmentation in the information resources represents a misalignment between the provision of information and the cognitive needs those resources are intended to serve, fragmentation manifested itself in at least two ways:

1. Firstly, information resources were characterized by a fragmentation of spatial distance
2. Secondly, there was fragmentation in medium, where the information needed for a single decision was scattered across paper-based, oral, tactile, digital, and other media

Firstly, information resources in the ICU were sometimes characterized by a fragmentation of spatial distance, meaning that information resources were often not physically where they needed them to be for the doctors purposes:

> *"…there is physical mechanistic fragmentation – I round here as a surgeon and there is certain info I look to extract: neurological status, GCS, vital signs, hemodynamic supports, feeds, urine output, lab values, chest x-rays, chest tube output, etc…and I know where to find all of those individually because I've been around. I have a routine, I first go to log A, then log B, etc…every unit charts things differently. So while you can find the same information the places you have to look is different. So labs are always on the system, but vitals sometimes are and sometimes aren't. If you are new to a service, the info you need is not routine.*

After you know what you need, then you have to figure out how to find it."
(Resident # 4)

"*I constantly have to check two places to look at one patient. …it is frustrating to constantly have to be here and here, and back and forth…*" (Nurse # 5)

A second related type of fragmentation that was often found in the ICU resources, related to the first point, was fragmentation in medium, where the information needed for a single decision was scattered across paper-based, oral, tactile, digital, and other media. Managing the information within each medium could be challenging because each one of these sources represented information in terms of their own logic, accepted their own type of input, updated information in distinct ways, and were monitored for feedback differently.

"*I find it really cumbersome that I have a set of data from vital signs, pressors at a certain rate, the MAR showing when I changed my pressor rate – supposedly (if I get to that), and then I have documented here in writing I changed my rate of my pressors. And my hope is that they are all saying the same thing – are they all reflecting the same time? I would hope anyone questioning me would have an appreciation for how busy I am and that this is not my priority. It is a lot of duplication that can lead to a misrepresentation. I wish we had one place to definitely write everything down. If you've seen it work well you can tell when it doesn't. I was one of the trainers for the EMR system, and it is so clunky.*" (Nurse # 2)

Practitioners also had difficulty thinking across different types of media platforms, because the types of information encoded and their representations sometimes differed widely. That is, each type of media had a tendency of encoding a different type of information, highlighting certain information characteristics, which were not commensurable with the characteristics encoded or represented in the others. It was unsurprising to me that a physician would voice the following:

"...it should be one system, not fragmented system where you take information from many places. If you're in an electronic based system, everything should be accessible electronically. To me the mixed system paper and electronic doesn't work. It makes no sense…" (Fellow # 2)

"So this system (i.e., the EMR system) doesn't give you an idea about how the patient is doing, because it doesn't give you any clinical parameters or any physiological parameters (like blood pressure). It doesn't give you any trends, any clinical notes from the physician, so as a result everyone is focused on writing on the computer, but…. Me: So if you want trends, or vitals, or …F: Then you have to go to the physical chart, but the chart doesn't record labs…so it's very fragmented" (Fellow # 2)

Strategies to compensate for fragmented information resources

As a response to the fragmentation of the information resources of the ICU, I noticed how physicians relied on two strategies to help them navigate and cope with the fragmentation across space and media. Firstly, physicians in the ICU were in the habit of keeping a patient worksheet, and secondly, physicians engaged in mobility work. In the first case, the patient worksheet was a personal piece of paper that was distributed to physicians at the beginning of each day. Physicians would inscribe them with relevant patient details throughout the day. The basic purpose of the patient worksheet was to remember and keep track of all relevant patient details, to place them in the context of other relevant information, and to represent them in a form that was most helpful for the physician's personal work. Even though many practitioners used the patient worksheet, not all practitioners liked using it. Because daily charting was a formal expectation of clinical practice (the chart being a legal information repository), physicians did not like the redundancy of writing the clinical details onto the patient worksheet. Yet the advantage of the patient worksheet was that the information could be inscribed into it easily, with a wider degree of representational flexibility than was typical of other media in the ICU,

and once inscribed, it was mobile and easy to carry around. Without it, highly dynamic and ephemeral details of clinical care would be quickly lost:

> *"The reason why I keep this document is that I know all of what happened yesterday based on how I updated it. Other staff will, instead of remembering, they'll ask the RT (what the settings were yesterday) or nurse: what was the hemoglobin yesterday and today? They don't put the onus on themselves, because it's a lot, but they'll expect others to pick it - the residents, RTs, NPs ...but you can still make decisions. And rounds just go a little differently. Instead of me asking at rounds – what were the settings yesterday? I'll be able to say: the settings were 10, 15 and 40% yesterday, today is better. I'll make a decision on it. The difference between me and another staff is that I do a lot more work for myself beforehand, and they can make a decision in the moment when they get the information. "* (Consultant # 7)

Another strategy that helped make information more relevant and contextual for the purposes of monitoring, and was used to overcome the barriers imposed by the resources was mobility work, which Bardram and Bossen (2005) describe as:

> "…the work needed to achieve the right configuration of people, resources, knowledge and place in order to carry out tasks."

Mobility work denotes the work of moving about to cover spatial distances in achieving the right configuration of information resources, and it is usually invisible to formal descriptions of the work involved in clinical decision-making (Bardram & Bossen, 2005). Still, in my findings I noticed how physicians, in engaging in regular forms of mobility work to add flexibility, mobility, dynamism and coherence onto otherwise disconnected and acontextual information. Mobility work sometimes came in the form of a deliberate visit to the office of a colleague to show them some clinical results or criss-crossing the patient's room in a sequence to check each information resource in light of the results of the other. Other times it would involve taking out the daily progress note, and placing it

alongside the nursing flowsheet in order to compare and contrast (only after which the right medical inference would be possible).

Keeping transitional artifacts (like the patient worksheet found in this ICU) and doing mobility work were strategies - by no means perfect in accomplishing their aim - that physicians use to counter the fragmentation among the information resources as they support monitoring and decision-making. The fragmentation that characterizes the information resources of the ICU is itself a by product an object-centric conception information, rather than a human-centric one. Where information is placed, and the way it is represented has, in this case, little to do with how physicians use it in the thinking and learning that serves their decision making. Because the information that is encoded in the progress notes, the flowsheets, or the monitors is not tailored to the dynamism, multifaceted and collaborative nature of medical expertise, the physicians have to overcome these limitations using active compensation strategies. These strategies were not perfectly effective in addressing the root of the problem, which was a misalignment between the information needs of clinical decision making and the type of information offered, the way that information was represented, and the location is was encoded in. In the next section, I develop the same theme – how the information resources are limited in their ability to support dynamic and distributed cognition – in the context of physicians plan medical care.

Planning

Planning patient care is a high-level, complex cognitive activity that arises out of reflection and action upon highly tacit mental models that physicians acquire through study and clinical practice. Seeing the process of planning unfold in the ICU is more difficult than those involved in assessment or monitoring. Planning relies more heavily on the expertise of physicians, which is not always amenable to being witnessed in the external ICU environment. Still, by observing how physicians respond to and reorganize their information resources in real time, I was able to detect a number of difficulties that physicians faced in planning care, and how they engaged with different resources of the

activity system to compensate for those difficulties. Interestingly, the way that physicians relied upon external resources sometimes produced unintended consequences and ripple effects throughout the activity system, which ultimately made planning and decision-making more difficult. In this section I show how physicians rely on external resources, such as interpersonal communications, technologies or both in order to get information that is more contextual, informative and relevant. However, in relying on their colleagues, physicians and other clinicians contribute to an environment of interruptions, multitasking and information overload, inadvertently rendering planning and decision making more difficult. In this section, I demonstrate these findings within four clinical illustrations that highlight the interactions among physicians, nurses and other information resources as they plan care and make decisions.

Clinical episode 1: Externalizing tangential aspects of the plan to ensure the ICU's ability to respond coherently as a whole team

In the ICU I witnessed that certain individuals in the clinical team would make a habit of externalizing and making universally available as many aspects of the plan as possible, for the benefit of the whole clinical team. These people acted like advocates for the plan, taking it upon themselves to inform and keep others updated. I wondered at this behavior and why it was necessary when information resources abounded in the ICU. Eventually I came to interpret this behavior in terms of some systemic inadequacies of information design that characterized the clinical notes, flowsheets, EMR pages, and order sets used to detail the plan. The plan is ultimately an abstraction held in the minds of physicians. While technically it is impossible to specify in exhaustive detail, yet it is nonetheless helpful to include as many members of the clinical team to as many of its aspects as possible. Often what is discussed in rounds, or what is recorded in the daily notes sets down only the most immediate aspects of the plan, while the tangential, back-up or conditional aspects of the plan remain the sole custody of the consultant. In complex cases, because physicians would rarely write these down, other members of the clinical team would take the opportunity to publicly 'pick the physicians' brain about certain foreseeable eventualities in the patient's condition – an exercise meant exclusively to encourage the doctor to verbalize their plan.

For example, in a complex patient, with a history of heart transplant, a pacemaker, and low renal function, two physicians were debating about the best approach to balance the function of the kidneys, heart and lungs. A key decision they were trying to make was whether and when to initiate the use of the dialysis machine, which acts as a temporary replacement of the kidneys and prevents renal failure. The purpose of the dialysis machine in this case was to relieve the kidneys and reduce the fluid overload in the patient's bloodstream (which the patient was not expulsing through urination). Use of the dialysis machine would also support the contractility of the heart. The two doctors were not agreed, one wanted to initiate dialysis immediately, and the other wanted to postpone dialysis, thinking that initiating that kind of major intervention might lead to a deterioration in the patient's condition. Normally in the ICU the clinical team will give Amiodarone to stabilize heart rate, but in this case, because the patient's transplant history Amiodarone was not indicated. Because of the non-traditional approach to tachycardia, the charge nurse made a point to stop the flow of conversation in rounds, and said:

> Nurse (# 4): "*so you want to push the tachycardia up, but how high is too high?*"
> Consultant (# 3): *"I think 150. Is that clear to everyone why we're pushing tachycardia up to 150, which would be abnormal for any other cardiac surgery patient?"*
> Nurse (# 4): *"I can see at 3am, when that heart rate goes up, someone is going to try to give Amiodarone, which would be the worst thing [i.e. - because of his transplant history]. What should they do instead?"*
> Consultant (# 3): *"Yeah, definitely don't give Amiodarone. Instead we should use Isopril"*

I asked her about this later, and she said:

> "*I feel that in a group everyone needs to be on the same page. I always like to talk about what-ifs, so that later on at 2 in the morning, I have a basis to stand on*

when I am talking to people later on. This is what we discussed, this is what the
plan was.
Me: You like making the plan explicit.
CN: Yes, and I want everyone to hear it." (Nurse # 4)

What the nurse was doing was taking ownership of the symmetry of available information across the whole team – making sure everyone had access to the same information, that everyone knew that everyone else had access to the same information, and that everyone understood the conditions that made that information relevant if they needed to act on it later on (Cramton, 2001). By making information equally available and understandable, she was ensuring the team's ability to act collectively if a situation arose overnight. When the information resources (e.g., notes in the chart, order sets, or other messages) fail to communicate the information they need, in the way they need it, doctors often resort to communicating directly with colleagues. In the remainder of this section I will seek to illustrate how physicians communicate and share information with one another as a way of compensating for deficiencies in the way that formal information resources provide information. That is, formal information usually failed to convey information in sufficient contextual detail to be useful, relevant or unambiguous.

Clinical episode 2: Relying on the surgical note to make a decision about coagulopathy

Even though direct communications with colleagues was the highest quality information available in the ICU, yet the way communication was carried out in the ICU, and the way it interacted with how information was made available sometimes produced situations in which the communications were themselves a source of interruption, cognitive burden and information overload. For example, in the meeting room, I witnessed an ICU intensivist who was trying to decide how to respond to a patient who was coagulopathic (his blood was too liquid, and as a result their post-operative bleeding was too heavy). The intensivist was relying on a note that the surgery resident had placed in the patient chart earlier that day, and which the resident brought to his attention. The note stated

simply that the surgeon ordered protamine not to be administered (the usual anticoagulative therapy), although it didn't explain why. The intensivist disagreed with the plan, but since he was not the MRP in this case, he could not make the decision independently. He paged the surgeon, and the surgery resident responded to the call. On the phone, the surgery resident informed the intensivist that the reason the protamine was not indicated was because the patient had a negative reaction to it. The surgeon (speaking through the resident) thought that no anticoagulative interventions needed to be made. The intensivist didn't agree. In his experience, he noticed that those patients who respond negatively to protamine once, are not likely to respond negatively to it when administered a second time. He felt that the patient was bleeding too much, and feared that this might cause the patient to '*bleed into her brain*'. Of course, because the authority resided with the surgeon, the intensivist had to convince him, and so asked the surgical resident to get the surgeon himself on the phone. They hung up, and about 10 minutes later the surgeon called back. The doctor made an argument that was based on his anecdotal experience, and reassured the surgeon that, if anything went wrong, he would "*suck it up on my end*". To this, the surgeon agreed to change the plan, following which the surgical resident (now on the ward) entered the order for another dose of protamine.

This example illustrates both how the formal clinical resources fail to support the decision-needs of doctors and the way in which direct (i.e., face to face or phone) communication is used to meet those unsupported decision needs. Specifically, the intensivist needed to learn about the patient's previous history of response to the anticoagulant (which was the basis for the surgeon's initial decision) and this was the contextual information that the clinical note failed to convey for the intensivist's decision-making needs. What is striking in this case, and many others like it, is the sheer number of back and forth communications required to get the right person in order to make the important, but relatively simple, decision. The surgeon wrote a note, which was followed by a verbal confirmation from the surgical resident to the critical care resident, who in turn brought it to the attention of the intensivist. The intensivist then called the surgical resident, who asked the surgeon to call the intensivist. Only when the surgeon and intensivist were on the phone together was the real authority and information at hand

to move the decision forward. Then, the intensivist, on the authority of the surgeon, had to direct the surgical resident to then enter another order into the EMR (because orders can only be altered by those who initiate them). Far from being atypical, decisions in the ICU – even minor ones – are very often characterized by these kinds of intense coordination requirements, which are only ultimately resolved through direct interpersonal exchanges. In the ICU, and hospital-wide, speaking to the right person is difficult, and for this reason I was not surprised at the words of a consultant:

> "*But what's hardest is the plan because its challenging to have multiple practitioners and services to agree on the plan, how are we going to move it forward, and coming to consensus is challenging as well. So I think the plan of how to get the patient well is, from an intellectual and communication standpoint the most challenging, one because of difference of opinion, and two because you're not always there at once to talk about the patient, like someone comes by the bedside, they say a few things and leave, an hour later, another group of docs come by, says something and leave, and a lot of times those docs are talking through people or through the chart.* Me: And so the feedback to build something together is not there. Consultant: A lot of times not…even if you have a simple patient, you'd think a simple plan, well...it takes a lot of services to agree to that, and it should be simple, but its easy for the details to get mixed up, we may all agree that they need the pacemaker, we may all agree that their heart is low, but the next steps are organizationally challenging sometimes.*" (Consultant # 2)

Another notable element in this case is the way that the limitations associated with the clinical note interacted with the need to reach out to a colleague. Because the description of the case in the note was insufficient for the decision-making purposes of the intensivist, he had to reach out by telephone to the person who wrote the note, and even in this case, this did not prove sufficient, so he reached out to the MRP. In this case, the need to reach out to the MRP was a partial consequence of the inability of the note and orders to codify in sufficiently meaningful detail why the surgeon declined protamine:

"There are multiple ways that we communicate and a few ways that are effective. Verbally, hand-written in chart, dictate notes on-line, etc…When its not effective, we sometimes don't understand the questions that we ask of each other, we answer different questions, or sometimes not fully get the subtlety of the questions we are asking of each other. The best by far is face to face. Certain people are effective with written communication but they're in the minority – a lot of time the note is just a rehash of what was said….Sometimes communication orders just appear without anyone knowing…So you call them, and then you get the answer that makes sense. So the EMR is not that effective for communication. Certainly its good because you don't have to read other people's hand writing, but if you have to make sense of something, if you have to make a decision, or if its something critical or something that you don't understand, then always a telephone call. Every time. You get different information, different subtleties of what's there, or you get clinical context, and that changes the interpretation." (Fellow # 3)

"I try to make a point of talking to them face to face (or call), especially if it is something more important or I'm not clear on something…if I'm looking about a minor issue (like ischemia), I'll just use the note, but if it's an arrest – a simple note… may not satisfy our concerns." (Fellow # 1)

In a modern ICU landscape, where so much change unfolds in the information and communication landscape, striking a balance between formal paper and EMR-based resources, with interpersonal communication is a vital challenge that has yet to receive adequate attention (Coiera, 2000). At times, the balance tips towards the latter, adding a heavy burden of communication traffic, which leads to interruptions and information overload. This was often because the formal information resources did not go far enough to specify a point in its context, which leaves the information needed for a decision ambiguous, uninformative, or irrelevant. Hence, doctors, nurses and other clinicians sought to externalize the information, to unsurface the contextual aspects of information

in order to ensure that there were no asymmetries in the availability of information throughout the team, and that the ability to make decisions collectively was intact.

> *"...the volume of information is so much that it can be overwhelming. Before you'd have to force yourself to pick and choose, but now there is so much there and its so accessible, you can almost overload yourself.…I would liken it to when our previous generation of physicians was doing anything, like daily work or colleagues, it had to be a phone call, personal meeting or letter from the secretary, so that limited the amount of volume of info that could be transferred between people, what you would generate and what you receive... now you can just sit there at your computer and you can send off an email, a text, put something on powerchart very quickly and all of that info is going to everyone else and its all there. So much of it is there that I can open my email at any moment and there are 10 new messages that come and the same thing happens clinically. At any moment there is so much info being put in the system that you can't deal with it sometimes. You can drown in the details…For example, if you look here* (showing me the message board on his desktop)*, there are all these messages that are irrelevant to me, and some are important, but they all say "URGENT"…. But 9.9 times out of 10 they're useless, so I may decide not to look at them anymore, and just miss them. There are 230 things here, so that's an example where useless information comes up and obscures the important stuff, but I have to ignore it all because I don't have the time for this*" (Consultant # 2)

Clinical episode 3: Using interpersonal communication to overcome difficulties computer order-entry

To better illustrate the effect that too many communications, and the influence that the formal information resources can have on clinical decision-making, consider an episode that I witnessed in the ICU, where a surgeon and an intensivist discussed the relative merits of the two anticoagulation approaches – daltaparin and heparin. The patient had been on heparin, but they decided to switch to daltaparin. When the new decision was made, the surgical resident logged into the desktop computer in the meeting room, and

revised the cardiac surgery post-operative order set (only surgeons can input or revise these orders, which are standard directions for the immediate post-operative period). While the surgeon put the order in, he forgot to remove the old order, and also failed to inform the nurse of the change. This is important, and is considered a violation of the norms of conduct in the ICU because the nurses and physician colleagues expect to be informed verbally of changes to the post-operative orders (that is, in addition to the notifications they receive from the order entry system):

> "*Things that are critical and can't be missed are told to us directly so it doesn't get lost in the paper. We trust if its important, it will be told to us*". (Nurse # 7)

While there is a mechanism in the CPOE to alert the nurses to new orders (a small glasses icon on the top left of the orders page), according to a consultant, it simply doesn't work effectively to alert the nurses:

> "*It really comes down to what you say to the nurse. The little glasses don't work. If a nurse is on break and an order goes in, she is liable to miss the glasses sign. We always supplement orders with a verbal check*" (Consultant # 5)

Because the surgery resident didn't remove the old order for heparin, the nurse was confused that both orders for anticoagulation were still on the list of orders: Did the physician really intend to dually anti-coagulate this patient, or was it a simple mistake? She thought, unsuccessfully, about reasons that might explain a dual anticoagulation approach for this patient. She was visibly frustrated, feeling that this was an instance of the trend of physicians to exclude the nurses from the clinical team:

> "*Prime example: change the MAR, don't tell the nurse*". In her opinion "*It happens all the time that the docs don't communicate their orders with the nurse*" (Nurse # 8)

The nurse, because the plan of care was not clear to her, sought to communicate with her clinical colleagues directly: she called the pharmacist (to no avail), and paged the intensivist (who by this time had left the ward). Ultimately, the intensivist called back and clarified that the plan had been updated, and that dalteparin was to replace, rather than supplement, the heparin. The scenario serves as a platform to better illustrate some of the difficulties that the EMR system imposes on nurse-physician collaboration. Firstly, with every order that physicians make, they have to supplement that electronic communication with a verbal confirmation, spoken directly to the nurse at the bedside (meaning they have to go to the bedside). Part of the reason why this has become standard practice is because the order-entry interface, which is where new orders appear is dense and untidy, and as a result the interface naturally obscures the new orders. To accommodate for this, the responsibility devolves on the physician to alert the nurse to a new order. In connection with this, the EMR system places an additional expectation on the physician – to "clean the orders" (i.e., scan through and remove irrelevant orders) as they expire, become redundant or are replaced. The order page on the EMR was messy partially as a result of the doctors' habit of not removing expired, redundant or irrelevant orders. Because the order sets on the system are not cleaned, the nurses don't read them through thoroughly – being habituated to a lot of extraneous and useless information on the orders page of the system.

> Me: "So the nurses aren't reading the communication orders?"
> "*Well eventually you stop reading them. The reason is that its way too much work, and particularly when people don't clean up the orders. The doctors are supposed to be at the bedside going through all the orders making sure they're current…We don't do a good job of keeping the orders clean, but it's very time consuming. It's the same thing with the meds. We have continuous infusions that the patients been off for days still sitting there. Its dangerous, especially if we have a change in team, and they wonder why they're there (i.e., the old orders). They might restart them…*" (Nurse # 9)

Secondly, even when the correct orders and communication orders are present, visible to the nurse, and the physician confirms that the nurse received them verbally, they are often written in such a way that they will remain ambiguous relative to emerging issues or certain aspects of the patients situation, and hence the overall effect of the order-entry system was to create more communications to resolve the ambiguity of the orders:

> "*It happens a lot that the patients don't fit in neatly in the criteria that they [i.e., the physicians] give. The orders are like reference material. Its not like a law; well, technically its law but there is a lot of interpretation to it. There are a lot of facts that aren't taken into account in the orders, because complex medical things always make it so that you're trying to balance different factors. These issues are often resolved in rounds, when you raise it and they give their judgment. Like take this communication order. It assumes that you're required to actually cool the patient to keep them under the target temperature, but he was cool on his own, so it was unclear when to move to the next stage of sedation. It says to cool to between 34-36 degrees, but for him he was already in this range. Should I still wait the 24 hours?* [The communication order specified to follow the hypothermia protocol, used after someone had an arrest and questionable neurological status, which states to allow 24 hours of patient cooling]. (Nurse # 9)

The ambiguity of the orders was amply demonstrated when, for example, the physicians would come to expect that, every time they would input orders for the whole ward, a wave of nurses (at approximately 9am, 4pm, and 9pm) to come ask for clarifications about the orders they were given. All the doctors in the ICU would anticipate this, and, after giving orders on rounds, would sit in the ICU meeting room and await the nurses who had difficulty grasping the substance, details or relevance of their orders.
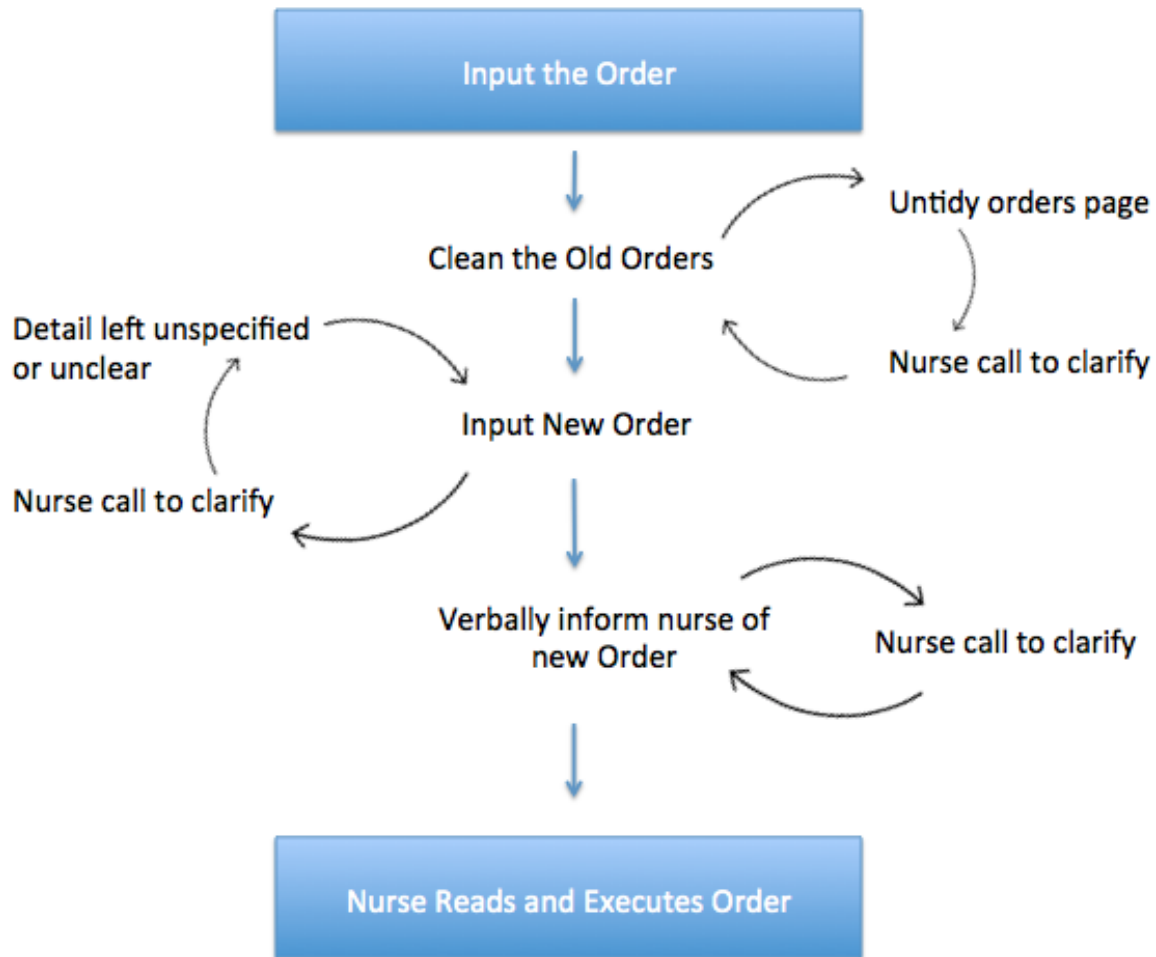
Figure 7. Depiction of a how additional steps and communications can follow the process of entering an order.

Part of the ambiguity of the orders was derived from the fact that they are implemented as a workflow specification device, and as a result, they seek to enumerate in great detail the actions that the nursing staff should undertake, rather than the logic of the plan of care. Hence, when expectations are specified at the level of behaviours of the nursing staff, the orders would quickly be inapplicable as soon as a patient variable would change. This would result in a situation in which a nurse would have to initiate a communication request to the physician for even minor issues. The result was a detail-oriented orders page that over-specified the behavioural and administrative aspects of care, which were often common sense. They read like legal documents – in part because they are legal documents, yet the consequence of this approach to supporting workflow made the orders

and communication orders onerous to read, and forced the attention of the nursing staff elsewhere for clarifications about the meaning and applicability of their orders.

> *"... there is just so much on here. Duplicates of a lot of orders… A lot of this I doubt would ever be written before the computer, but now because we have infinite space on the computer and such ease of access, its all on there. Probably for the sake of minimizing litigation. Sometimes you find someone where there will be far too many order sets. One of them is to order blood products – but once they're ordered. Get rid of that!..... In [Another hospital] you write the order and it just eventually gets pushed to the back of the order list, and it gets forgotten about. It's not in anyone's way any more. But here, when you try to see what's relevant in patient care orders, the other info is in the way – like 'peripheral IV insertion' – this didn't need to be here and now its in the way. Nobody even writes that! On a regular order, I'd never write "start an IV" – it's obvious. Definitely could have ben excluded from the order set."* (Resident # 3)

Clinical episode 4: Simplifying decision tasks by relying on knowledge organized and presented through technology

I saw one ICU fellow try to find the reason for a patient's elevated heart rate and uncomfortable breathing. In this case the fellow supplemented the clinical notes and results review page with information external to them (e.g., verbal communications, internet searches, or using medical apps) to systematically eliminate their list of differential hypotheses. Wondering about the cause of the elevated heart rate and blood pressure, the fellow at the bedside initially considered a new infection, pain, and new clots as possible explanations. To investigate them further, he checked the results review on the EMR, and searches for the trend in the white blood cell count (passing his finger along the horizontal grid of cells). Because he sees that it trended down over the past several hours, this leads him to believe that it is not a new infection. While he was on the results review page, he noticed (because it was highlighted in red) that the blood platelet count was also high, and this lends credence to the hypothesis that a new clot may be the

cause of the elevated heart rate, but an elevated platelet count might also be explained by musculoskeletal damage or an inflammatory disorder. The elevated platelet also moves him away from his initial hypothesis of pain as the cause of elevated heart rate – because it suggests that there is a biochemical reason to explain the heart rate. He considers the possibility of inflammation more seriously, and then moves to the patient to double check his clinical assessment and examine the patients' body more closely. Not noticing any signs of inflammation, the resident accesses the clinical documents to bring up the most recent x-ray. As the resident told me "I make sure to check this first, before I ask the nurse because I don't want her to bias me". Still with no evidence to support his hypothesis of inflammation as a cause of the elevated heart rate and platelet count, the fellow interrogates the nurse. After searching through several sources of information (results review page, nurse, x-ray, clinical assessment and progress notes), the fellow doesn't emerge with any evidence to support his hypothesis of inflammation, but he concludes that: "its encouraging, I'm less concerned that she's getting worse". Even though there is no obvious explanation for the clinical symptoms, the patient demonstrates several things that make an elevated platelet count less concerning (e.g., they are responding well to their beta-blocker, they recently underwent a catheter change, or the clinical team was able to remove the lines to their neck).

In this case, no one piece of information from the electronic or paper resources was enough to fully exclude the list of differential hypotheses that the fellow entertained. As he was retaining the possible conditions in his working memory, he was scanning through the resources and opportunistically seeing which piece of information would "jump out at him" to rule out a potential diagnosis. In this case, an elevated heart rate is not in itself a subject of great concern, but rather something to be monitored over time, waiting in order to gather more evidence of a deeper cause for concern. If there were more evidence, the fellow would have likely taken recourse to a closer study of the chart, or seek the opinion of other members of the clinical team. Importantly, the way the lab values and patient condition were presented through the resources was not enough to rule out any particular differential diagnosis. To do so would have required some real engagement with the

resources because the fellow was looking for several values in conjunction with one another, in light of the patient's history, and their clinical presentation, all over time.

Interestingly, the fellow relied on the technological features of the results review page to direct his plan of care. The results review page, in presenting the values of the blood work, selectively highlights for the physician those results that lie outside of a pre-specified range. Relying on this highlighting feature of the results review page to direct the physician's inquiry was a very common strategy in the ICU:

> "Me: So, you use the highlighted results review a lot?
> *Consultant: Oh yeah, we use it all the time. It's very helpful.*" (Consultant # 5)

The fellow was merely 'scanning the surface' to make sure no obvious source of concern stood out. He is in a state of readied awareness – not searching per se, but scanning and keeping an open eye to the suggestions of the technology (Weick & Sutcliffe, 2006). In this state, the physician uses the technology to help him ignore lots of information that will probably not be relevant to this case. Because medical knowledge is usually densely interconnected, there are several paths of reasoning that might lead to the same conclusion, and the physician takes advantage of this feature of medical knowledge in order to not engage with certain questions or inquiries unless absolutely necessary. Furthermore, because the technology actively suggests certain avenues of reasoning or inquiry, the physicians will hitch a free cognitive ride, taking advantage of the particular indicators or values of interest that the technology suggests. Without the technology, the task of actively monitoring options can become cognitively daunting, and the physician might be susceptible to red herrings, confusion or other forms of distraction. In the words of one physician:

> *"Say the platelet count is 10, I may not actually look at that because its one piece*
> *of 1000s of data points that I could look at and I just can't do it, so I'll rely on*
> *someone else, the nurse to say, this guys has…or powerchart it comes up in red,*
> *and if it does I investigate further. A lot of times it's a meaningless value, but*

sometimes is meaningful. We can't look at all the data points because we don't have the time and ability to keep them all straight, so we pick and choose the ones we think are representative of the overall picture, and then if we see problems with them, we jump to the other issues that are related to those. Its' sort of like a tree and we move done, so, for example, the platelet count, we'll look down at the drugs they're on that effect platelets, and then if they're on those drugs, well when did they start them, then get all these other data points." (Consultant # 2)

While this strategy is useful, it comes with its own potential perils. In general, many physicians with whom I spoke acknowledged that the way information was presented to them had a large effect on what issues were addressed, what problems were constructed as active, and how the patient was managed in general. As a result, this strategy of organizing the investigations around issues that are raised through the technology may have a more profound shaping effect in influencing judgment that it may perhaps seem on the surface. Most notably, the way that technology puts forth information can serve to produce an availability bias, where decision-making is shaped by those factors that are available and ready-at-hand, rather than the best ones (Mamede, van Gog, van den Berge, Rickers, van Saase, van Guldener & Schmidt, 2010; Stead et al., 2011):

"...very annoying: on this system the hemoglobin value, once it hits 70 shows up as red – critical. Why? Why do all of the nurses get worked up when hemoglobin hits 70? Why is that the value we need to transfuse at? It's the value that was selected in some of the early transfusion trials - it being the restricted arm of the transfusion trial, when patients with a hemoglobin less than 70 did significantly better than those with higher than 70. So we think 70 is the magic number to transfuse. Its just the number they chose. So why should a hemoglobin of 69 be bright red and 71 be blue, be a cause of concern when the margin of error for hemoglobin is 10%? No reason at all. But the presentation prompts an action. It forces a binary decision,"'is this a critical value or not?', when in reality the decision is much more complex" (Resident # 4)

Beyond the results page that presents objective clinical markers, the same principle applied to information gleaned from the clinical notes, the monitor, and EMR resources, which shape and provide structure to decision-making.

> *"…I think the presentation of data is very important… the way that data becomes available to you has a big impact on how you manage a patient."* (Resident # 2)

> *"…if there is no monitor then you'll be oblivious of it until you circle around and ask for it. That will immediately call you to action, for example, if the monitor shows a high heart-rate or a low blood pressure.* Me: It becomes the first cue, whereas maybe its not the most vital cue. *R: Or the alternative, where it may be the most vital cue, but not being presented to you, so you don't recognize it. So that info if its immediately presented to you may cause to act immediately, if there is an abnormality, or if it isn't presented to you, may miss a call to action."* (Resident # 2)

In the ICU, making the decisions involved in planning care involves relying on clinical colleagues, technologies, and paper resources, yet relying on these information resources can present a number of challenges. In this section I have shown that physicians rely on interpersonal communications, transitional artifacts, and other means of simplifying their decision-making tasks as a result of the individualism, objectivity, and fragmentation of their information resource. These methods of simplifying decision-making, however, come with their own peril, and create ripple effects across the ICU, which often go unrecognized by individual practitioners in the ICU (Coiera, 2000). In the next section I summarize these findings, clarify their implications, and suggest measures to support the dynamic and distributed nature of medical expertise.

Chapter 5 Discussion

The field of medical decision-making is changing. Several converging forces have had a drastic effect on both the way that information is provided in ICU environments and the structure of the decisions needs of the physicians who use that information. These changes, while conferring several opportunities on the decision making process, simultaneously introduce new challenges to thinking and reasoning in the ICU. One major element of the changing information landscape is the introduction of new technologies, which influence the presentation of information, the way decision tasks are organized (Patel, Kushniruk, Yang & Yale, 2000), and the very vision underlying patient care itself (Swinglehurst, Greenhalgh & Roberts, 2012). Another important element of the changing healthcare environment is new emphasis on collaboration, which makes medical decision-making more decentralized and puts a premium on effective communication (Boreham, 2004; Lingard, 2012).

As the environment in which information is made available changes, the very nature of decision-making also changes. Traditional conceptions of decision-making (and the methodologies used to study them) have made the implications of this point difficult to see, and the central motivation underlying this dissertation has been to explore the consequences of a systemic, distributed conception of decision-making as it relates to information design and decision support in acute medical environments. My findings show how information provided in the ICU, while intended to support clinical decision-making (1) fails to do so on a number of counts (See Table 3 below), and (2) in attempting to do so simultaneously introduces a numbers of unanticipated side effects that change the tasks associated with clinical decision-making and inadvertently make it more difficult.

In the remainder of this section I will tackle three tasks. Firstly I will summarize the ways that information provided in modern ICU environments fails to support the dynamic and distributed decision needs of physicians. Secondly I will illustrate some of the consequences of these failures for making decisions in the ICU. Thirdly, I spell out what

these failures mean for supporting knowledge intensive decision-making work in the ICU and other socially and technologically involved environments.

Misalignments between information resources and the dynamic and distributed decision needs they serve

Considering the system of information resources in the ICU, my findings demonstrate a number of manifestations of a traditional approach to decision-making and decision-support: information resources are objectivist, inflexible, fragmented and individualistic.

Objectivist and detail-oriented

As an overall trend, information resources, whether embedded in the EMR or the chart, were characterized with an objectivist bias (reflective of a general trend in health information systems, Wears, 2012). Relative to the multifaceted, layered and dynamic decision needs of the clinical staff, the information resources tended to be static, discrete, and detail-oriented. There was a tendency to encode and represent information in a way that is highly standardized and structured, emphasizing its use for clearly intended purposes or activities (Rosenbloom et al., 2011). Yet often the thinking needs of physicians were not tethered in a straightforward way to discrete activities - and when they were, they would often change in a rapid and often kaleidoscopic manner. At any given time, physicians would have several ongoing activities, each with attendant questions. They would have information needs that were multifaceted – dealing simultaneously with several aspects of the individual patient, the clinical problem, and particular areas of medical knowledge in a single scope (Smith, 1996), and where information needs would be organized at several levels of abstraction simultaneously (Patel, Kaufman & Kannampallil, 2013). Any of these could be foregrounded or backgrounded as opportunities for information arose, and hence the decision-making of physicians was extremely dynamic.

Difficulties in using information for Decision-Making	Explanation of Information Difficulties
Objectivist and detail-oriented	Objectivism is an approach to providing information in relation to an abstract version of what medical care to the "average" patient looks

	like, rather than an approach to support that focuses on physician-centered processes of thinking and reasoning in the here and now.
Lack of dynamism and inflexibility	In general, the information resources of the ICU were not amenable to being modified to suit the local needs of the practitioners using them.
Fragmentation across and within the information resources	The information resources were characterized by a piecemeal approach to information design. Clinicians used a variety of resources, each with their own representational scheme, their own sources for information, their own methods of update, etc…
Individualism and lack of support for the cognitive activity involved in collaboration	Information resources were largely designed to support individual physicians in their awareness and understanding of the patient. Supporting shared awareness, and the capacity of the team to think and reason as a group was not common.

Table 3. Areas where narrow conception of decision-making fail to support the real decision needs of expert physicians.

In this connection, problems and difficulties often arose as a result of the misalignment between a static system of ICU information resources, and the dynamic nature of medical decision-making. When a practitioner needs to abstract and resituate the information, they will seek to decontextualize it from its current setting, and place it in the context of other pieces of attending information (Berg & Goorman, 1999). For example, when a patient's blood pressure spikes above the expected range, a physician will naturally seek to interpret the elevated blood pressure in the context of this history, and will seek the patient flowsheet to see what the trend of blood pressure has been over the course of the day. If the physician finds that this elevation in blood pressure runs counter to the trend, then they will wonder what their blood pressure was upon admission to hospital, and whether there is a precondition or social factor that would help him interpret its significance. At this point, they may engaged in a targeted search through the clinical notes viewer, where they may be required to "*sift through a lot of the repetition and garbage to get to the key things*" (Resident # 2). When information is presented in an overly objectivist or static way, or within the context of too many details, physicians recounted having difficulty moving up the abstraction hierarchy, leaving behind the inessentials, and resituating the main idea into a new context. Hence, rather than supporting the physician's movements of thought, the information resources would often serve to distract and splinter attention and burden working memory.

Information in the ICU is objectivist in that is provides information in relation to a linear train of decision-making that is connected to an abstract version of what medical care to the "average" patient looks like, rather than support the processes of thinking and reasoning that support making decisions in the here and now. Among the consequences of this objectivism is that, while physicians are provided with consistently organized information resources, yet because they are not organized around the processes underlying clinical thinking and decision-making, physicians must spend more time and effort to satisfy their decision needs. They must invest more effort in sifting, searching, assessing, comparing, contrasting, questioning, abstracting, and otherwise manipulating the information resources. This can have negative implications for patient care, when, for example, considered in light of the fact that physicians have many questions that simply go unanswered because the investment in time and energy to answer them is prohibitive (Ely, Osheroff, Chambliss, Ebell & Rosenbaum, 2005; Smith, 1996).

More than having a direct negative impact on the ability of a single physician to think and reason with the information resources, the objectivist trend produced systemic consequences that were only visible at the level of the whole activity system. Consider, for example, Figure 8 portraying a variety of consequences that can all contribute to the diminishing capacity of physicians to think, reason and make decisions on the ICU ward. The figure illustrates how information that is overly discrete, while intending to facilitate decision-making, can paradoxically make it more difficult.
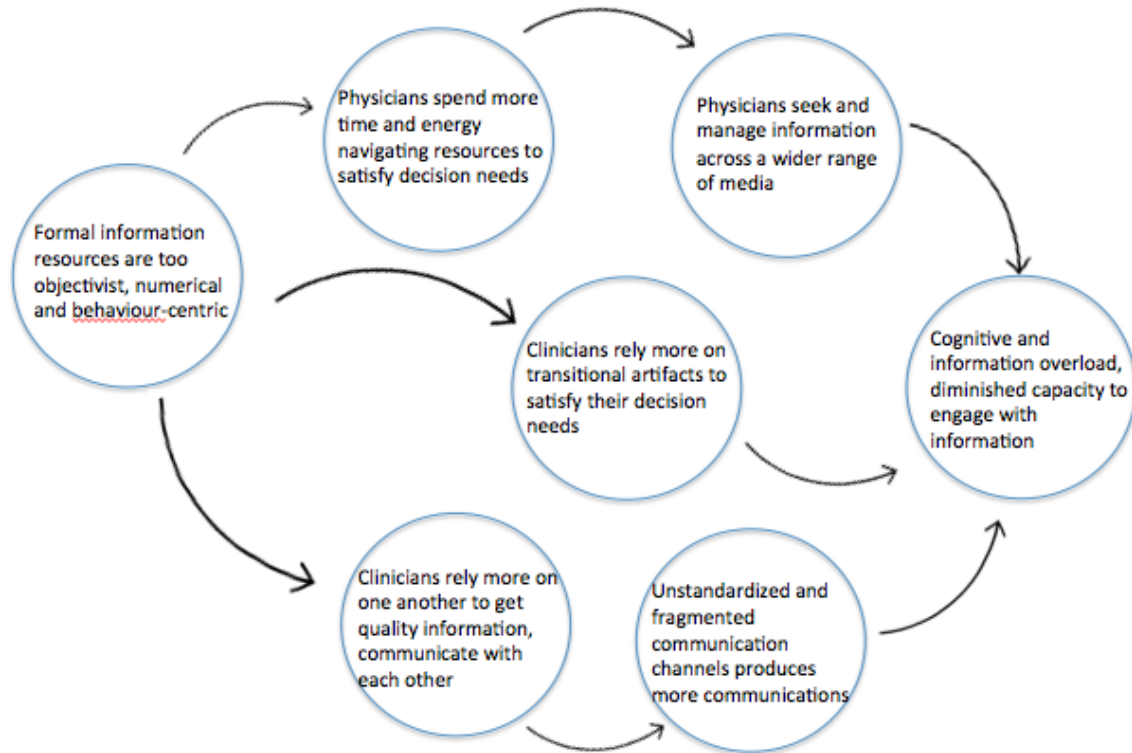
Figure 8. Depiction of a series of consequences that follow from an objectivist approach to clinical decision support – paradoxically rendering decision-making more difficult.

Fragmentation among the information resources

On the whole, the approach to information provision was piecemeal in the ICU. The ICU presented physicians with information across an array of uncoordinated systems that existed side by side, each performing its own respective function in its own way, each from its own vendor, each with its own logic of representation and access. For example, in conducting a patient assessment, it was the norm that physicians would go to the bedside infusion pump to look at what drugs the patient was on, the bedside monitor for the blood pressure and heart rate, the chart for clinical history, the bedside nurse for details about the past few hours, and the EMR system for lab and blood work. The problem with the fragmented approach to information provision was that physician's decision-making process did not respect the piecemeal approach. For them, the discrete pieces of information that they collected across the information resources were part of a single decision making process, which was often punctuated, interrupted, and frustrated through spatial and representational gaps in the information. Because of this there was

sometimes a sense in the ICU of being disjointed, working within the distinct demands and expectations of several resources which have little relationship or bearing to one another (as one senior physician put it "*it's like working in someone else's head*", Consultant # 6).

Another dimension of the piecemeal approach to providing physicians with information was the gaps in how information was represented. As one senior physician (Consultant # 4) complained, decision-making was hindered in the current ICU informatics environment because of a lack of integration among different modes of representation (i.e., clinical images such as X-rays, patient assessment – which is visual and tactile, patient physiology – often encoded in numerical and graphical presentations, and clinical notes – which are textual). It was often difficult for clinical staff to think across representational formats, to understand how information about different aspects of the patient was to be understood in light of different information encoded in a different platform. The process of extrapolation, mutual comparison and placing distinct units on a common plane of reference often went unsupported, and because of this the emergence of higher level thinking and a comprehensive awareness of the patient's condition was rendered more difficult (Patel et al., 2009).

As a response to the piecemeal approach to information, physicians and other clinicians had their own ways of compensating (See Table 4 Below), adding dynamism and coherence to the otherwise static and fragmented set of resources. To introduce mobility and coherence to the resources, physicians would develop practices to move and manipulate information in ways that was not formally supported (Bardram & Bossen, 2005). For example, during daily charting, physicians would take the patient chart and flowsheets into the ICU room, sit at a desktop computer, and lay them out so as to show them in light of each other. This would highlight a broader scope of the patient's clinical picture. When a desktop computer wasn't available, the ability to lay documentation out into an array was compromised, and physicians would often be involved in a juggling act in an attempt to use the physical space around them to see their resources to the best advantage, holding papers up or placing them side by side.

Physicians would also use transitional documentation, such as the patient worksheet, as a way to keep abreast of the patient details and remind them of important connections in the resources. The patient worksheet was flexible, and could help the physicians overcome spatial and representational gaps among their resources. However, by the same token keeping a patient worksheet was an added burden on an already heavy load of clinical documentation. Many practitioners did not like keeping a patient worksheet on top of other documentation (which were legally mandated). As a result some physicians would find other ways to work around using the information resources directly: they would leave the responsibility to other members of the clinical team and base their judgment on the information given to them by others, or they would simply satisfice their decision-making (hedging their information needs).

Compensation Strategy	Explanation of Compensation Strategy	Systemic consequences of the compensation strategy
Mobility Work	Mobility work is how physicians "…move from patient to patient, from place to place, from one piece of technology to another, and from one source of information to another to make the right configuration of people, places, resources and knowledge emerge" (Bardram and Bossen, 2005).	Moving from one resource to another, contending with the representational and spatial gaps can hinder the emergence of higher-level thinking.
Relying on Interpersonal Communication	When information is not suited to their decision needs, physicians reach out to clinical colleagues (through synchronous or asynchronous channels) to resolve the information need.	Adds to the information sources that physicians use. This can produce a culture of interruption, which results in different forms of cognitive burden and information overload
Keeping paper Records/Using Transitional Artifacts	Physicians will often keep a personal daily record of the information they need. Usually in the ICU this is an open, blank piece of paper.	Adds to the documentation that physicians have; physicians have to manage information across a wider range of resources
Hitching a Free Cognitive Ride on Technologies	Instead of engaging with the information resources in depth to satisfy their information needs, physicians will often resolve the need by relying on the active framing or suggestions of technology when they are available.	Relying on the way technology makes information available and represents it can serve as a precondition for availability and framing bias.

Table 4. Overview of strategies that ICU physicians use to cope with misalignments between information resources and their decision needs.

Ultimately, the fragmentation found among the information resources is due to the fact that the ICU is not designed as a whole system. Some of the information resources have been part of the ICU for many years (e.g., clinical notes), others were developed exogenously and recently implemented (e.g., the order entry system, EMR), and still others have been recently developed endogenously (e. g., the flowsheets, admission sheet). Each of the elements of the information landscape was developed with different visions of information support, different assumptions about the nature of clinical work, and different goals. To support distributed and dynamic decision-making, the ICU must be treated as one continuous information landscape. The current environment of the ICU, consisting of different representational schemes, and different logics of information organization and access, imposes a burden on the clinicians who work in it.

Lack of Dynamism and Inflexibility

When information resources do not support directly the needs of those who use them, one ubiquitous strategy that is seen across environments where humans perform knowledge intensive work is to create and manage endogenous information resources that are used alongside formal ones – these supporting more contextual work needs in relation to the ones supported through the formal information resources (Hutchins, 1995; Kirsh, 1996; Pennathur, 2013). Work in modern acute care environments is no exception, and I sometimes witnessed physicians create their own endogenous artifacts to help them in using the formal and institutional ones. However, in the culture of modern hospital environments, where information is subject to so much standardization and bureaucratic oversight the physicians' ability to create and manage their own information is severely curtailed, and as a result adapting the environment for cognitive congeniality is difficult. In general, physicians and other members of the clinical staff were expected to conform to the way that information and decision support were offered by the formal resources. This was true at many levels:

1. The characteristics of the information (e.g., level of abstraction, detail, subjectivity),

2. The way information was represented (e.g., textual, graphic, image, numerical, etc...)

3. The location of the information in the ICU (e.g., in the chart, on the EMR, at the bedside, etc…)

All of these aspects of the information were standardized, or subject to professional norms. For example, resident's charting, patient monitoring, and handoff were all practices that were subject to a high degree of standardization and the norms of professional conduct. While this in itself is not a bad thing – indeed the right types of standardization are very helpful (Wears, 2012) – yet when the force driving standardization runs counter to the needs of clinical thinking, then this can undermine the ability of the clinical team to think and reason at a high level. This was the situation I witnessed in the ICU, where physicians were frustrated because the technologies and information resources that were imposed on them did not directly support the way they liked to think about care, and gave them no flexibility to alter the information to suit their needs.

Consider this point in the context of research conducted by Rosenbloom et al.'s (2011), which investigated how physicians used clinical notes, and how the format and structure of those notes influenced clinical work. The author's argue that clinical documentation is often designed to serve bureaucratic and administrative purposes, rather than clinical ones. They state that neither the bureaucratic nor clinical approach be prioritized, but rather that information resources should be flexible, giving the clinical user the choice: "…typically, for a given sites' implementation, computer-based documentation systems are usually configured to take clinical input primarily in narrative or structured form, but not both. Most computer based documentation systems that the authors have seen do not support hybrid documentation in the way that we recommend…" (Rosenbloom et al., 2011).

Where possible, information resources in the ICU need to be flexible to accommodate the idiosyncratic preferences of the practitioners who use them. Giving practitioners control

over the kinds of information they work with, the kinds of representations that information is encoded in, and where the information is located can go a long way to supporting practitioners to create knowledge in context. However, where flexibility in the information resources is not an option, more work can be done to support doctors in their ability to create and use transitional documentation, and their capacity to annotate their information resources.

Individualism and Lack of Support for the Cognitive Activity Involved in Collaboration
For better or for worse, physicians in the ICU rely heavily on communications with their clinical colleagues (especially face to face, telephone, and other synchronous methods of exchange) to get the information they require for decision-making. Some have called the issue of how to simultaneously support personal information needs and collaborative communication needs "the central dilemma of collaborative work environments" (Hermann Miller, 2008). My findings illustrate some of the difficulties that this balance entails.

Consistent with existing literature, I found that physicians often tended to stop short in their search of information through formal resources, and opted instead for direct interpersonal communication (Sweenen et al., 2013). As a result, physicians and other members of the clinical team tended to over-rely on direct communication with colleagues to overcome problems associated with getting information from the chart or EMR. That is, when information resources were difficult to access or use, cumbersome, irrelevant or disorganized, there was a tendency to communicate with colleagues directly (e.g., through phone, email, text message, or opportunistic exchanges). My findings suggest that overreliance on direct communication with clinical colleagues may stem from information design considerations, namely, the objectivism, inflexibility, and fragmentation that characterized information resources. To illustrate, consider how the clinicians I interviewed universally reported how valuable they find face to face communication. Face to face, and other forms of open, synchronous communication are rich and responsive. They allow physicians to establish their own common ground, and resolve problems in a just-in-time way. No other information resource in the ICU

provided this type of dynamic, integrated and contextually-relevant information. They can encode a physician's experiences and interpretations of their experiences in a way that account for the relevant contextual features of the situation. Face to face communication is valuable to physicians in part because it can easily provide high level information (e.g., an expert colleagues' recorded experiences, assessments, or interpretations of those experiences) that will assist physicians in establishing the organizing "frame" that will orient the patients care. Other times these conversations provide the comfort and confidence that comes from the subjective interpretation or judgment of a trusted professional colleague (Smith, 1996). The physicians I interviewed recounted that this level of information was difficult to record, even in a clinical note, which were structured by certain professional norms and other constraints. At the same time, the penchant towards synchronous or face to face can contribute to an interruption-driven environment (Parker & Coiera, 2000; Patel et al., 2008). Misuse of communication strategies contributes to an environment of interruption, cognitive overload, distraction and multitasking (Laxmisan et al., 2007). Cognitively, communicating with peers in this way can have consequences beyond mere interruption, since it can interfere with the higher level thinking, reasoning, and decision-making, which are sensitive to erosion, vulnerable to bias, and difficult to maintain (Kirsh, 2000; Potter, Wolf, Boxerman, Grayson, Sledge, Dunagan & Evanoff, 2005).

Hence, more attention needs to be paid to how the information from paper-based, computational, and human resources merges together in the process of making a decision. Under what circumstances does each contribute effectively to a wider decision-making process, and when do they tend to undermine one another? One major avenue forward in this regard lies in better support for the cognitive activity associated with collaborative work. That is, when a team is planning and administering care, practitioners must have access to shared information, but more than this, they must also have access to each other's interpretation or assessment of that information (Boland & Tenkasi, 1995; Ellingsen & Monteiro, 2003b; Reddy, Dourish & Pratt, 2001). In acute care environments, especially when a patient's trajectory is uncertain, access must be rapid and reflective of the patient's continually evolving status. This kind of collaboration can

be well served by group technologies, shared databases, visualizations and representations that track the progress and evolution of information (Teasley, Covi, Krishnan & Olsen, 2000; Sutton and Hargadon, 1996; Hargadon, 1999; Xiao et al., 2008). This kind of information – that which would help a physician view the assessments and judgments of their peers was not systematically available, and as a result collaborative work would suffer from inefficiency and be more prone to error.

To summarize, an array of reasons combine to produce the result that doctors and other members of the clinical team over rely on direct, synchronous communication strategies because the information embedded in the paper or computer resources were too inflexible, clumsy, redundant or uninformative, and furthermore, did not support 'social' knowledge – that is the knowledge and inferences needed to support teamwork and social cognition.

Some Recommendations

Providing access to well-organized and aggregated information, no matter how clear and consistently available it is, is not enough. Health information must be practitioner-centric. It must be sensitive to the needs that doctors and other practitioners have to turn knowledge into contextually sensitive working knowledge. This implies making it sensitive to their cognitive needs, their latent expertise, and to the way that practitioners use their environment to satisfy their intellectual needs – the technologies that surround them, physical space they work within, and the social relationships they use as information channels. Properly seen, none of the information resources in the ICU is entirely separate – physicians move fluidly between them to acquire their needed information and when one source is problematic, physicians tend to rely on another. Yet despite the interconnectedness and interdependence among these channels of information (social, material and technological), a culture in decision support to view and design these as separate and independent entities persists.

A major contribution of this thesis lies in its utilization of a distributed cognition approach to highlight the wider consequences of local information design choices.

Firstly, more attention needs to be paid in health informatics and decision support interventions to the quality of information that is used to support decision-making. As we have seen, physician's expertise is multifaceted, layered, and highly dynamic, and yet the information they use often interferes with their thinking process. This need not be the case. Information can be designed around a physician's need to abstract and elaborate, to navigate, compare or perform any other number of operations on data. One step forward would be to use graphical representations and other images, since these can express highly meaningful, rich and contextualized information quickly.

Secondly, more attention is needed to the coherence of information resources with respect to a physician's ability to use them in expert thinking and decision-making. Information design choices are never inert. The way information is presented influences how physicians set up and execute work tasks, and can even influence how physicians formulate and envision the very goals of patient care (Swinglehurst, Greenhalgh & Roberts, 2012). When information design choices are inconsistent with one another, this has a disruptive effect as physicians have to navigate through them. In the ICU, information resources are often the result of piecemeal interventions that reflect more the wishes of hospital management than the clinical staff that uses them. The ICU is a whole system, and the relationships among the information resources in the ICU must be thought of and designed as a whole to ensure the coherence of experience.

Thirdly, physicians need information that supports collaborative awareness of what other members of the clinical team think of the patient. Especially when the ability to work as a team is vital, tools and technologies that support the symmetry of knowledge are key. Many physicians I spoke to felt that recent changes in the technology that supports clinical work have made collaboration among clinical staff simultaneously more frequent and less informative. Because decision support is designed primarily to support clinical workflow, structured and organized around the behaviours that are assumed to make up clinical practice, this has drawn attention away from informatics support that fosters shared awareness of a commonly held patient situation.

Limitations

First, the literature review was thorough, but not exhaustive, and my own biases may have affected the choice of journals, keywords and other related search and selection criteria. This approach to literature review can raise some questions about transparency, if anyone were to attempt to replicate the search.

This research focuses on a wider breadth than is typical of analyses of cognitive work, and sought to document the real-time unfolding and use of information by practitioners. This focus necessarily brings with it strengths as well as limitations. Because I sought to study decision-making in context, I cannot lay claim to objectivity as it is traditionally conceived. I myself was a part of the setting I studied, and I drew the boundaries around the phenomenon of interest. To counter my own biases and limitations on the study of ICU decision-making, I engaged regularly in reflexive journaling, I spent a long time in the field, I diligently pursued negative or contradicting opinions, and I sought to triangulate my findings through different types of data.

Despite the breadth of my data, there were some limitations imposed on the study by the scope of my ethics approval and the fact that I was the only researcher. Firstly, because of the ethics committees concerns about patient privacy, I was not granted access to look directly through patient data, and this limited me from following a number of elements that form an important part of the information and communication landscape of the ICU. For example, I did not look at the phones, emails of physicians, or the messages they sent and received over the EMR's messaging system. I sought to remedy these limitations through observations and directed interview questions, but there were simply a number of elements that contribute to decision-making that were impossible to see in real time, and very difficult to reconstruct after the fact. Secondly, studying a dynamic system like the ICU requires being aware of the simultaneous action at many parts of the system, but, because I was alone, this level of awareness was not possible.

The ICU in which I conducted my field research differed from many ICUs in that it specialized in post-cardiac surgery care. Because the care was more specialized, it was

more amenable to standardization than what is perhaps the case in general service ICUs. Despite the differences, I do not have reason to believe that the principles that I arrived at through my data would be fundamentally altered when applied to different types of ICU settings.

Similarly, the ICU setting I investigated was at an intermediate stage in the rollout of its EMR capabilities. It had not yet implemented the full scope of the EMR system (in one sense one could say that it did not have an full EMR system). As a result the ICU was in a transitional period (albeit a long-lived period of transition!), where clinicians used a hybrid system of older paper technologies and new digital ones. Doubtless this presents some barriers to developing theory about the use of technological information in decision-making, but along side the challenges this ICU presented a wonderful opportunity to witness the interaction among paper, people and technology as they interact and contribute to making decisions possible. This latter question was the primary goal of the thesis.

Concluding Remarks

This work, in contributing to the literature on distributed cognition, is part of a relatively young tradition in cognitive science, and still younger in health informatics and medical decision-making. The transition from seeing cognition as the capacity of an individual to seeing it as the property of people, paper and things working together in a social and cultural milieu has radical implications for information design, decision support, and technology and instruction design.

Looking at the wider system that shapes how decisions are made brings home the fact that in highly structured work environments no decision is made outside of the context that makes it possible. Perhaps more than any other point, my investigation showed that decisions are the result of contending forces, communities and values, each with their own stake in how decisions are made, and their own vision of what constitutes good medical care. These contending forces were not far below the surface of daily practice, and had a direct impact on decision-making that was difficult to estimate. Among clinical

staff there was cynicism and resistance to the recently implemented EMR system, and each community held their own gripes about it, as well as about the other users of the system. Clinicians sometimes perceived their information resources more as an agent of control than of support, and reactions to using the available resources ranged from acceptance, to resistance, workaround and sabotage.

In this kind of milieu, how can one support decision-making without the range of unintended consequences that have been so well documented in the research literature? Investigating decisions through the lens of distributed cognition can help us map agreement and alignment of vision at a deeper level than what is traditionally considered in studies of medical cognition. This kind of analysis, of the social and cultural milieu that makes ICU knowledge possible, is not within the scope of this current study, but it is a much needed direction of investigation if decision support is to be met with more consistent results.

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Appendices

Appendix 1: Ethics Approval Documentation

LAWSON
HEALTH RESEARCH INSTITUTE

LAWSON FINAL APPROVAL NOTICE

LAWSON APPROVAL NUMBER: R-16-313

PROJECT TITLE: Distributed Cognition in the Intensive Care Unit: Coordination and the Flow of Information in Medical Decision-Making

PRINCIPAL INVESTIGATOR: Dr. Nicole Haggerty

LAWSON APPROVAL DATE: October 21, 2016

Health Sciences REB#:   107875

Please be advised that the above project was reviewed by the Clinical Research Impact Committee and Lawson Administration and the project:

Was Approved

Please provide your Lawson Approval Number (R#) to the appropriate contact(s) in supporting departments (eg. Lab Services, Diagnostic Imaging, etc.) to inform them that your study is starting. The Lawson Approval Number must be provided each time services are requested.

Dr. David Hill
V.P. Research
Lawson Health Research Institute

All future correspondence concerning this study should include the Lawson Approval Number and should be directed to Sherry Paiva, Research Approval Officer, Lawson Health Research Institute, 750 Baseline Road, East, Suite 300.

cc: Administration

Western University Health Science Research Ethics Board
HSREB Full Board Initial Approval Notice

Principal Investigator: Dr. Nicole Haggerty
Department & Institution: Richard Ivey School of Business\Ivey School of Business, Western University

Review Type: Delegated
HSREB File Number: 107875
Study Title: Distributed Cognition in the Intensive Care Unit: Coordination and the Flow of Information in Medical Decision-Making

HSREB Initial Approval Date: June 22, 2016
HSREB Expiry Date: June 22, 2017

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Letter of Information & Consent		2016/06/22
Other	Letter from the Director of the CSRU outlining permission to conduct the study (Received for Information)	
Western University Protocol	Received June 8, 2016	
Other	Letter of Introduction	2016/06/17
Instruments	Interview Questions	2016/06/17

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Ethics Officer: Erika Basile ___ Katelyn Harris ___ Nicole Kaniki ___ Grace Kelly ___ Vikki Tran ___ Karen Gopaul ___

Appendix 2: Information and Consent Form

Richard Ivey School of Business
University of Western Ontario
1151 Richmond Street North
London, Ontario N6A 3K7

TEL 519.661.3206
FAX 519.661.3485
www.ivey.uwo.ca

LETTER OF INFORMATION

Dear CSRU practitioner,

You have recently been notified by the director of the CSRU of a research project taking place on the ward, and we would like to invite you to participate. The goal of our project, entitled *Distributed Cognition in the Intensive Care Unit: Coordination and the Flow of Information in Medical Decision-Making,* is to better understand how medical practitioners use information, and how the information they encounter in their environments can be better suited to their decision-making needs.

Because the content and context of medical decision-making is changing so rapidly, medical practitioners are expected to stay up to date with a growing body of medical knowledge, balance a variety of considerations in their medical decisions, and familiarize themselves with ever-new tools that assist them in the decision-making process. Our research aims to help organizations, medical practitioners and ultimately patients as they deal with these changes. We have obtained permission from the CSRU at University Hospital to conduct this study, and following the project we will prepare a report of our findings for the hospital, as well as articles for leading academic journals in our field.

You are being invited to participate in this project because of your role in medical decision-making in the CSRU. Participating in this study means that you consent to allow us to observe your work, take notes about how you use information, and ask occasional questions. It also may imply taking part in a brief interview (no more than 20 minutes), which, with your permission, would be audio recorded (although audio-recording is not compulsory). The interview can take place at any location that is convenient for you.

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study (in part or entirely) at any time without consequence (e.g., to your employment, academic status, income). You do not waive any legal rights by participating in this research study. We anticipate our data collection to last between 2-4 months, and for data analysis and results dissemination to be

completed within a year. We anticipate that 20-40 people will participate, and we would be happy to forward a copy of the findings to you if you are interested.

You will not directly benefit from this project and there are no known risks to you in participating. However, our aim is to improve the information used in medical decision our research and thus you may benefit indirectly. No identifying information gathered in this study will be released to your organization or to anyone else. Your name will be replaced by a pseudonym in our observation and interview data. This data, along with any audio recordings, will be stored for seven years on a password protected computer and encrypted file format and accessed only by the research team.

Qualified representatives of the following organizations may look at your medical/clinical study records at the site where these records are held, for quality assurance (to check that the information collected for the study is correct and follows proper laws and guidelines). Examples include: Representatives of Lawson Quality Assurance Education Program, Representatives of the University of Western Ontario Health Sciences Research Ethics Board that oversees the ethical conduct of this study.

Please feel free to contact either of us at any time if you have additional questions or thoughts regarding the research. If you have any questions about your rights as a research participant or the conduct of the study you may contact the Office of Research Ethics at Western University, (519) 661-3036. There are no conflicts of interest to declare related to this study.

Anthony Naimi   Nicole Haggerty
PhD Candidate, Health Information Science   Associate Professor, Information Systems
Faculty of Information and Media Studies   Ivey Business School
The University of Western Ontario   The University of Western Ontario

Dr. Ahmed Hegazy
Assistant Professor, Anesthesia and Perioperative medicine
Schulich School of Medicine and Dentistry
The University of Western Ontario

CONSENT FORM

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

PARTICIPANT:

_____
SIGNATURE

_____
NAME (please print)

_____
DATE

PERSONAL RESPONSIBLE FOR OBTAINING CONSENT:

_____
SIGNATURE

_____
NAME (please print)

_____
DATE

☐ I agree for my interview to be audio-recorded
☐ I do not agree for my interview to be audio-recorded

Appendix 3: Semi-structured Interview Guide

1. What is the most important part of your job?

2. Can you tell me about the most difficult part of using the system* in your work?

3. Are there aspects of your work that the system does not support well? How does the system not support your work well?

4. Are there aspects of your work that the system does support well? How does it support it well?

5. What is the hardest kind of information to get access to and use in your work?

6. What is the most intellectually challenging part of your job?

7. Do you find any information resources frustrating to use? If so, which ones and why?

8. How has your work changed since the computer system was implemented in your hospital?

*Depending on the conversation, I would interchange "system" with flowsheets, chart, MAR, clindocs, EMR, orders page?

Appendix 4: ICU Admission Note

CLINICAL PROGRESS RECORD

DATE AND TIME FOCUS / PROBLEM	DATE AND SIGN ALL ENTRIES
	CSRU Admission Note

ID:

PMH:

Cardiac Risk Factors
Hypertension — *high bp*
Hyperlipidemia — *high cholesterol in blood*
Diabetes — *high blood sugar*
Smoking —
Obesity
Family history

Medications

Allergies:

pre-op

Pre-op Investigations:

heart has 4 valves

TTE/TEE (date   )
LVEF = *left ventricular ejection fraction*
RV =
Aortic valve = *valve between LV & aorta*
Mitral valve = *valve between left atrium & left ventricle*
Tricuspid valve =
Other

Cath (date   )
LVEF
L main
LAD = *left anterior descending*
Cx =
RCA = *right coronary artery*
Other

Other

PAGE NO

DATE AND TIME FOCUS / PROBLEM	DATE AND SIGN ALL ENTRIES

during + after surgery

OR Details

Surgical Procedure:

Issues in OR:

Pump time ___ min.; cross clamp time ___ min

Pre pump TEE	Post pump TEE	Lines
LV EF	LV EF	___ radial AL
RV	RV	___ femoral AL
PAP	PAP	___ internal jugular (triple lumen, SG)
AV	AV	___ IABP
MV	MV	
TV	TV	

Pressors/ Inotropes		Chest Tubes	Pacing
Vasopressin (units/hr)		mediastinal	Atrial wires
Norepinephrine (mcg/min)		pleural	Ventricular wires
Epinephrine (mcg/min)		Blake drain	Set rate
Milrinone (bolus: ; mcg/kg/min)			Set rate
			Threshold

Total IV heparin: Total IV protamine

Cormack _____ view   intubation: BMV:

Physical Exam

CNS: temp   PERL   mm   sedation:

CVS: rhythm: Art line BP: NIBP:

     HS: dressing D&I   SC emphysema:

     Femoral pulse/bruit: pedal pulses:

Resp: (vent settings) FiO2 ___ ; mode ___ ;Peep
     PO2   PCO2   pH   lactate
     Air entry:

GI: abd   BS

GU: foley catheter

Plan:
1. Wean sedation, allow to wake
2. Wean ventilator to extubate

Appendix 5: Nursing Assessment

12 HOUR NURSING ASSESSMENT/ INTERVENTION FLOWSHEET

DATE: _____ ICU DAY NO _____
(YYYY/MM/DD)
KEY: * = Significant Findings   TIME OF ASSESSMENT: _____

NEUROLOGICAL / COMFORT
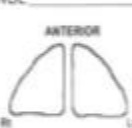
☐WDL GCS: _____ GAG: ☐YES ☐NO   COUGH: ☐YES ☐NO   BLINK: ☐YES ☐NO
☐C-SPINE PRECAUTION ☐CEEG MONTAGE ☐IMPEDANCE WDL
☐RESTRAINTS CONSENT FOR RESTRAINT: ☐YES ☐NO RATIONALE FOR USE: _____
 TYPE/LOCATION: _____
☐EVD INSERTION DATE: _____ ☐EVD LEVEL: _____ (cm) ☐WAVEFORM POSTED IN CHART
CSF: ☐CLEAR ☐BLOOD TINGED ☐CLOUDY ☐_____
PAIN SCORE (NRS 0-10/10 or CPOT 0-8/8): _____   VAMAAS GOAL: _____   ACTUAL VAMAAS: _____
INCISION / DRESSING: _____
SEDATION PLAN: ☐SPONTANEOUS AWAKENING TRIAL   ☐WEANING   ☐MAINTAIN

RESPIRATORY

☐MASK ☐NASAL CANNULA ☐VENTILATOR ☐CPAP _____ ☐BIPAP _____
FiO₂ _____ NO _____ PEEP: _____ AC/SIMV: _____ PS: _____ VC/PC: _____ INTUBATED: ☐ORAL R/L/Mid ☐NASAL R/L ☐TRACH
CHEST EXPANSION: ☐WDL _____ ETT secured at _____ (cm)
TRACH SITE: ☐WDL _____ RESPIRATIONS: ☐WDL _____

B	BRONCHIAL
C	CRACKLES
W	WHEEZE
↓	DECREASED AIR ENTRY
■	ABSENT AIR ENTRY
N	NORMAL

ANTERIOR   POSTERIOR

CHEST TUBE SITE	SUCTION	FLUCTUATES	LEAKS	TYPE OF DRAINAGE

CT DRESSING: ☐WDL _____

HOB: ☐≥30° OR _____ RATIONALE: _____
ACTIONS: ☐KEEP SpO₂ ≥ _____ SAT PROBE TYPE: _____ Date Applied: _____
VENTILATION PLAN: ☐MAINTAIN   ☐WEAN AS TOLERATED _____
 NEW/WORSENING RESPIRATORY SYMPTOMS: ☐YES ☐NO   IF YES, ARI SCREENING TOOL: PASS / FAIL

CARDIOVASCULAR-HEMODYNAMIC

ECG LEAD: _____ ANALYSIS: _____   ☐STRIP POSTED IN CHART

ARTERIAL PULSE	RAD	BRACH	AX	FEM	POP	DP	PT
0-Absent 1-Bounding	R						
1-Weak 3-Doppler							
2-Normal	L						

CAPILLARY REFILL: ☐BRISK ☐PROLONGED
PERIPHERAL EDEMA: _____
SKIN COLOUR: ☐WDL ☐_____
BP: ☐NIBP ☐ART. LINE SITE: _____ WAVEFORM: ☐WDL ☐_____ SKIN TEMP: ☐HOT ☐WARM ☐COOL
 ☐ART. LINE SITE: _____ WAVEFORM: ☐WDL ☐_____ ☐CLAMMY ☐DIAPHORETIC
PACEMAKER: ☐Epi ___V ___A ☐TV_____ ☐TC ☐Permanent   VTE PROPHYLAXIS: ☐AES ☐IPC ☐CHEMICAL
MODE: _____ RATE: _____ UNDERLYING RHYTHM: _____
THRESHOLD: _____ mA: _____ SENSITIVITY: _____ ☐Battery symbol **NOT** present
☐PAC: LOCKED: ☐Yes ☐No POSITION: _____ (cm)
☐IABP: SITE: _____ MODE: ☐Auto ☐Semi TRIGGER: _____
 FREQUENCY: _____ ☐WAVEFORM POSTED IN CHART AUG % _____ AUG ALARM _____
INCISION / DRESSING:
_____ ☐WDL ☐_____
_____ ☐WDL ☐_____

NURSE'S INITIALS: _____

8403-0725 (Rev. 2016/06/07) REFERENCE SCRIC INTENSIVE CARE UNIT   PANEL 1 of

INTRAVENOUS

IV SITE	SOLUTIONS (Concentration / Dose)

GASTROINTESTINAL

ABDOMEN: ☐ SOFT ☐ FIRM ☐ DISTENDED _____

BOWEL SOUNDS: ☐ WDL ☐ HYPER ☐ HYPO ☐ ABSENT   DATE OF LAST BM: (YYYY/MM/DD) _____

FECAL MANAGEMENT SYSTEM TYPE: _____   INSERTION DATE: (YYYY/MM/DD) _____

DIET: ☐ NPO   ☐ TPN   ☐ ENTERAL _____   ☐ ORAL _____   ☐ SUPPLEMENT _____

VIA: ☐ FEEDING TUBE   ☐ GASTRIC TUBE   ☐ G TUBE   ☐ G/J TUBE

INSERTION SITE: ☐ ORAL ☐ NASAL R / L   DISTANCE: _____ (cm) TIP PLACEMENT: ☐ GASTRIC ☐ DUODENUM ☐ JEJUNUM

☐ GI PROPHYLAXIS   ☐ PROKINETIC   ☐ INSULIN PROTOCOL   ☐ STOOL CHART IN USE

STOMA TYPE: _____   APPEARANCE: _____

DRAINAGE TUBES:

TYPE OF TUBE	LOCATION	DRAINAGE SYSTEM	DRAINAGE
1.			
2.			
3.			

DRESSING: _____

GENITO-URINARY

VOIDING: ☐ CONTINENT   ☐ INCONTINENT

CATHETER: ☐ URETHRAL   INSERTION DATE: (YYYY/MM/DD) _____   ☐ SUPRAPUBIC   SIZE: _____   TYPE: _____

☐ ILEAL CONDUIT   ☐ URETHERAL STENT   R / L   ☐ CATHETER SECURED   ☐ CBI

URINE AMOUNT: ☐ WDL _____

COLOUR: ☐ PALE YELLOW   ☐ AMBER   ☐ DARK AMBER   ☐ CLOUDY   ☐ _____

DIALYSIS: ☐ INTERMITTENT   ☐ CONTINUOUS ☐ PERITONEAL   DIALYSIS CATHETER SITE: _____

PERINEUM: ☐ WDL _____

INTEGUMENTARY

BED TYPE / SURFACE: _____   BRADEN SCALE: _____

ACTIVITY: ☐ BEDREST ☐ MOBILIZATION PLAN: _____

☐ FALLS RISK ASSESSMENT   ☐ WOUND FLOWSHEET IN USE

SKIN CONDITION: ☐ WDL _____

OTHER

RESUSCITATION STATUS: _____   ADDITIONAL PRECAUTIONS: ☐ CONTACT ☐ AIRBORNE   ☐ NEGATIVE PRESSURE IN USE / ASSESSED

BLOOD TRANSFUSION CONSENT: ☐ YES ☐ NO   ☐ DROPLET ☐ DROPLET/CONTACT

ARMBAND ON PATIENT: ☐ YES ☐ NO _____

☐ PROVIDE EMOTIONAL / INFORMATIONAL SUPPORT TO PATIENT AND/OR FAMILY AND/OR FRIENDS

CAREGIVERS NEEDED FOR ADL: ☐ 2-3 ☐ 4 or MORE

NURSE'S INITIALS: _____

NO.	NURSING ASSESSMENT/INTERVENTION	TIME													
1.	NEUROLOGICAL														
2.	RESPIRATORY														
3.	CARDIOVASCULAR														
4.	GASTROINTESTINAL														
5.	GENITO-URINARY														
6.	INTEGUMENTARY														
7.	COMFORT / SEDATION														
8.															
9.															
10.															
11.	ACTIVITY / MOBILITY														
12.	LAB WORK														
13.	PLAN-OF-CARE														
14.	PATIENT / FAMILY EMOTIONAL SUPPORT / EDUCATION														
	NURSE'S INITIALS														

NO.	TIME	SIGNIFICANT FINDINGS D = Data A = Action R = Response / evaluation	INITIAL

8460-5725 (Rev. 2016/06/07)   REFERENCE SONC INTENSIVE CARE UNIT

DELIRIUM SCREEN

Delirium screen completed @ _____
Step 1: NRS/CPOT_____
Step 2: VAMAAS: _____ (MAAS < 2 ICDSC = U/A)
Step 3: ICDSC Total _____ (circle + items)

- LOC
- Inattention
- Disorientation
- Hallucinations/Delusions

- Psychomotor agitation/retardation
- Impaired speech/mood
- Sleep/wake disturbance
- Symptom fluctuation

NO.	TIME	SIGNIFICANT FINDINGS D = Data A = Action R = Response / evaluation	INITIAL

Appendix 6: Nursing Flowsheet

FLOWSHEET

DATE: _____ (YYYY/MM/DD) ICU DAY NO: _____

INTERVENTIONS (✓ = Care completed WDL; * Significant findings; Initial when completed/assessed)

TIME	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07

POSITIONING Activity Code: C = Chair CP = Chair Position D = Dangle S = Stand with Weight Bearing A = Ambulation SL = Straight Lift P = Prone

- Degree HOB elevation (< 30 requires *DAR)
- Supine / Right / Left
- Rev Trendelenburg
- Activity (Use Code)

CHEST CARE Code: L = Left R = Right B = Both P = Percussion Mode V = Vibration Mode D = DB·C CA = Cough Assist BS = Breath Stacking MP = Mechanical Percussion

- Chest Physio
- Bed Rotation
- Percent Rotation
- Pause Time
- Percussion/Vibration
- Duration in Minutes

HYGIENE Bath Code: C = Complete P = Partial

- Bath
- Skin Inspection
- Shower
- Hair Wash
- Pericare
- Linen Change
- Facial Shave
- Collar Care
- Change ECG Electrodes

ORAL CARE

- Oral Inspection
- Toothette
- Teeth Brushed
- Lip Care

EYE CARE Code: P = Patched

BOWEL ROUTINE Stool Code: Sm = Small Mod = Moderate L = Large S = Soft D = Diarrhea H = Hard M = Melena Impaction Code: H = Hard S = Soft N = None

- Stool Record
- Impaction ✓
- Fecal Incontinence System Irrigation

RESPIRATORY

- Ties / Tapes Changed
- ETT Site Changed
- Trach Care
- Chest Tube Dressing Changed and Dated
- Chest Drainage Unit Changed
- SpO$_2$ Monitor Site Changed / Assessed
- Speaking Valve

INITIALS

8460-1004 (Rev. 2014/10/06)   PANEL 5

FLUID BALANCE

KEY: T△ = Enteral Tubing Change

Weight: _____   Time: _____

INTAKE										OUTPUT						CHEST TUBES	
ORAL	ENTERAL FEEDS	MEDS & FLUSH	COLLOID							HOUR						L	D
										0700-0800							
										0800-0900							
										0900-1000							
										1000-1100							
										1100-1200							
										1200-1300							
										1300-1400							
										1400-1500							
										1500-1600							
										1600-1700							
										1700-1800							
										1800-1900							
										TOTAL							

12 HOUR INTAKE _____   12 HOUR OUTPUT _____   BALANCE _____

INITIALS: _____

INTAKE										OUTPUT						CHEST TUBES	
ORAL	ENTERAL FEEDS	MEDS & FLUSH	COLLOID							HOUR						L	D
										1900-2000							
										2000-2100							
										2100-2200							
										2200-2300							
										2300-2400							
										2400-0100							
										0100-0200							
										0200-0300							
										0300-0400							
										0400-0500							
										0500-0600							
										0600-0700							
										TOTAL							

12 HOUR INTAKE _____   12 HOUR OUTPUT _____   BALANCE _____

24 HOUR INTAKE _____   24 HOUR OUTPUT _____   BALANCE _____

PREVIOUS 24 HOUR BALANCE _____

INITIALS: _____

Patient's Name:

	BP	1930	2000	2030	2100	2130	2200	2230	2300	2330	2400	0030	0100	0130	0200	0230	0300	0330	0400	0430	0500	0530	0600	0630	0700
TEMP °C (T)																									
Cooling / Warming																									

MAP (–)
SBP cuff ∨ art X
DBP cuff ∧ art X
PULSE •

BP scale: 220, 210, 200, 190, 180, 170, 160, 150, 140, 130, 120, 110, 100, 90, 80, 70, 60, 50, 40, 30

PULSE CODE: R = Radial B = Brachial A = Axilla F = Femoral Pop = Popliteal DP = Dorsalis Pedis PT = Posterior Tibialis

ALARM RANGE: SpO₂	
ECG	
BP	
SpO₂	
ZERO (Z) LEVEL (L)	
PAP S/D	
PAP M	
CVP	
CI	
SVRI / PVRI	
PULSES: Right	
Left	

SUCTION CODE: 1 = Small 2 = Mod 3 = Copious M = Mucoid P = Purulent B = Bloody

TOTAL RR	
PIP	
MINUTE VOLUME	
FiO₂	
AC / SIMV	
PC / VC	
PS / PAV / PEEP	
NIV: IPAP / EPAP	
MASK / NP / TMASK	
SUCTION: ETT / TRACH	
SUCTION: NT / OT	
CT: B / F / D	

BLOOD GLUCOSE	
INSULIN RATE units/h	

VASOACTIVE MEDS CHART DOSE

INITIALS

NEUROLOGICAL RECORD

PUPIL SCALE (mm)
1
2
3
4
5
6
7
8

	TIME	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
ALERT: Awake																									
DROWSY: Oriented and sleepy																									
CONFUSED																									
STUPOROUS: Eye opening to pain only																									
COMATOSE: No eye opening to pain																									

PUPILS
+ = Brisk
S = Sluggish
– = Fixed
U/A = Unable to Assess

		TIME	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
RIGHT	SIZE																									
	REACTION																										
LEFT	SIZE																										
	REACTION																										

GLASGOW COMA SCALE

				08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
EYE OPENING (C = Eyes Closed by Swelling)	SPONTANEOUSLY	4																									
	TO SPEECH	3																										
	TO PAIN	2																										
	NONE	1																										
BEST VERBAL RESPONSE (T = Endotracheal Tube OR Tracheostomy)	ORIENTED	5																										
	CONFUSED	4																										
	INAPPROPRIATE	3																										
	INCOMPREHENSIBLE	2																										
	NONE	1																										
BEST MOTOR RESPONSE (N = Neuromuscular Blocking Agent OR Barbiturate Coma)	OBEYS COMMANDS	6																										
	LOCALIZES	5																										
	WITHDRAWS	4																										
	FLEXION	3																										
	EXTENSION	2																										
	NONE	1																										
	TOTAL SCORE	15																										

LIMB MOVEMENT

RECORD RIGHT (R) AND LEFT (L) SEPARATELY IF THERE IS A DIFFERENCE BETWEEN THE TWO SIDES.

		08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
ARMS	NORMAL POWER																									
	MILD WEAKNESS																									
	SEVERE WEAKNESS																									
	SPASTIC FLEXION																									
	EXTENSION																									
	NO RESPONSE																									
LEGS	NORMAL POWER																									
	MILD WEAKNESS																									
	SEVERE WEAKNESS																									
	EXTENSION																									
	NO RESPONSE																									

EVD		08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
	Drain level to tragus																									
	Drain open																									
	Zero																									
ICP Monitoring	ICP Waveform																									
	ICP																									
	CPP (MAP - ICP)																									

Comfort: Refer to pain, sedation and delirium scales. **Sleep Codes:** Identify periods when patient appears to be sleeping. **QS** = Quiet Sleep **RS** = Restless Sleep **A** = Awake

Report to MD if ICDSC > 4		08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
	Pain: NRS or CPOT																									
	VAMAAS																									
	ICDSC (0-8)																									
	Sleep																									

Comfort Meds: Chart continuous infusions of sedatives, narcotics and neuromuscular blocker (dose)

	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
INITIALS																								

MONITORING OF INVASIVE LINE SITE(S)

KEY: ✓ Indicates = (1) Solution infusing at prescribed rate **OR** Venous access lock patent   (2) Waveforms WDL   * = Significant findings (documentation on A/I Flowsheet required)
(3) Dressing dry and intact **OR** if site visualized: absence of redness, swelling or tenderness   TΛ = IV tubing change
Λ = Redness   B = Positional   C = Pain   D = Occluded   E = Interstitial   F = Dislodged   I = Initiated   Δ = Dressing change   DC = IV / NS lock discontinued

DATE LINE INSERTED	LIST ALL CENTRAL AND PERIPHERAL VENOUS AND ARTERIAL LINES	TIME												
	INITIALS													

INTERVENTIONS (✓ = Care completed WDL; * Significant findings; Initial when completed/assessed)

TIME	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	01	02	03	04	05	06	07
RESTRAINTS ON / OFF																								
R Wrist Restraint																								
✓ CSM																								
L Wrist Restraint																									
✓ CSM																								
R Ankle Restraint																									
✓ CSM																								
L Ankle Restraint																									
✓ CSM																								
Waist Restraint																									
VTE PROPHYLAXIS ON / OFF																								
AES (Anti Embolic Stockings)																								
IPC (Intermittent Pneumatic Compression)																								
*Skin ✓ Legs																								
MUSCULOSKELETAL ON / OFF A = Active P = Passive AA = Active Assisted																								
Splints · Upper Extremities																								
Splints · Lower Extremities																								
ROM · Leg																								
ROM · Arm																								
GENITOURINARY Code: L = Latex Catheter S = Silicone Catheter																								
Catheter & Bag Change																								
Bladder Pressure																								
FAMILY Code: V = Visit P = Phone																								

OTHER DRESSINGS/CARE   * = Significant findings (Documentation on A/I Flowsheet Required)

INITIALS																								

ANTHONY NAIMI

LANGUAGES	English, French
CITIZENSHIP	Canadian
CIVIL STATUS	Married

EDUCATION

2012-2018   Western University
PhD in Health Information Science *(Defended, degree conferred June 2018)*
Thesis: Supporting dynamic and distributed decision making in acute care environments: Insights from a cognitive ethnography.

2009-2011   University of Toronto
MA in Cognitive Psychology
Thesis: Investigating the Role and Nature of Prior Knowledge in Conceptual Change.

200520-09   Concordia University
Honors BSc, GPA: 4.12/4.30
Major: Psychology; Minor: Science College (Multidisciplinary Studies in Science)

PUBLICATIONS

Sedig, K., **Naimi**, **A**., Haggerty, N. (2017). Aligning information technologies with evidence-based healthcare activities: a design and evaluation framework, *Human Technology, 13(2), 180-215.*

Sedig, K., Parsons, P., **Naimi, A.** & Willoughby, K. (2015). Reconsidering health care evidence as dynamic and distributed: the role of information and cognition. *International Journal of Evidence Based Healthcare*, 13(2), 43-51.

Harris, R., Wathen, N., MacGregor, J., Dennhardt, S., **Naimi, A**., & Ellis, K. (2015). 'Blaming the Flowers for Wilting': Idealized Aging in a Health Charity Video. *Qualitative Health Research, 26(3), 377.*

MacGregor, J. C. D**.**, Wathen, C. N., Kothari, A., Hundal, P., & **Naimi, A**. (2014). Strategies to promote uptake and use of intimate partner violence and child maltreatment knowledge: An integrative review. *BMC Public Health, 14(1), 1.*

CONFERENCE PRESENTATIONS, INVITED TALKS & POSTER PRESENTATIONS

Conference Presentations
Naimi, A. & Crossan, M. (2014). Multilevel knowledge translation in health care: bridging practice and cognitive perspectives. Presented at *Organizational learning, knowledge and capabilities* (OLKC). Oslo, Norway, April 22-24, 2014.

Dunbar, K. N., Petitto, L.A., Jasinska, K., Bhasin, S., **Naimi, A**. Forster, E., Ahmed, F., Jowkar-Banani, G. (2011). Simultaneous imaging of neural activations of women and men in real-time conversation using fNIRS. Presented at *The Society for Neuroscience, November 13, 2011.*

Auger, N., Daniel, M., Pless, B., Lyons, C., **Naimi, A**., Knäuper, B. (2009). LIGHT IT UP: Do youth perceive pro-tobacco messages in advertisements marketing hockey equipment? Presented at *The 6th National Conference on Tobacco and Health, November 1-4, 2009.*

Invited Talks
Naimi, A. (2014). Practice based approaches to Organizational Learning. Guest lecture in "Knowledge Translation", seminar taught by Dr. Anita Kothari, Feb. 6, 2014.

DOCTORAL COURSES & SEMINARS

2012-Present <u>Western University</u> London, Ontario

Faculty of Information and Media Studies:
- Social Contexts of Information (Winter 2014 with Dr. Nadine Wathen)
- Interdisciplinary Issues in Health Information Science (Fall 2012 with Dr. Nadine Wathen)
- Consumer Health Information Sources and Services (Fall 2012 with Dr. Jacquelyn Burkell)

Faculty of Health Studies:
- Qualitative Methods (Winter 2015 with Dr. Deborah Rudman)
- Perspectives in Knowledge Translation (Winter 2013 with Dr. Anita Kothari)
- Health Informatics (Fall 2012 with Dr. Candace Gibson)

Richard Ivey School of Business:
- Organizational Theory (Audit, Fall 2013 with Dr. Jennifer Howard-Grenville)

TEACHING ASSISTANT EXPERIENCE

2017-Present <u>University of Toronto, Mississauga</u> Mississauga, Ontario

Department of Communication, Culture and Information Technology
- Signs, Referents and Meaning (Fall 2017, CCT 210 with Lisa Peden)
- Data Analysis (Fall 2017, CCT 226 with Dr. Gerhard Trippen)
- Communications Research Methods (Fall 2017, CCT 208 with Dr. Jeffery Boase)

2012-2017 <u>Western University</u> London, Ontario

Faculty of Health Studies
- Introduction to Health and Ethics (Winter 2015 with Dr. Ramona Fernandez)

Faculty of Information and Media Studies
- First Year Foundations (Winter & Fall 2016, MIT 1025 with Dr. Paul Benedetti)
- Navigating Media Culture (MIT 1050, Fall 2015 with Dr. Norma Coates)
- History of Communication (MIT 2000, Winter 2014, MIT 2000 with Dr. Daniel Robinson)

- Designing and Critiquing Research Methods (MIT 3000, Fall 2013 with Dr. Robert Babe)
- Political economy of Media (MIT 2100, Winter 2013 with Dr. Jonathan Burston)
- History of Communication (MIT 2000, Fall 2012 with Dr. David Spencer)

2009-2011   <u>The University of Toronto</u>   Toronto, Ontario

Department of Psychology
- Statistics for Psychology (Fall 2011 With Dr. Douglas Bors)
- How the Child Discovers Language (Winter 2011 with Dr. Laura-Ann Petitto)
- History of Psychology (Fall 2010 with Dr. Zac Campbell)
- Psychology and the Scientific Mind (Fall 2009 & Fall 2010 with Dr. Kevin Dunbar)
- The Psychology of Prejudice (Fall 2010 with Dr. Michael Inzlicht)
- Social Psychology Laboratory (Summer 2010 & Winter 2011 with Dr. Connie Boudens)
- Scientific Communication in Psychology (Fall 2010 with Dr. Connie Boudens)

Rotman School of Management
- Leadership from the Inside Out: Building Relationship Skills that Work (Winter 2010 & Winter 2012 with Dr. Melanie Carr)