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Exploring Macrocognitive Healthcare Work: Discovering Seeds for Design Guidelines for Clinical Decision Support

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ABSTRACT

Modern healthcare can be described as a macrocognitive work system. In such systems, people seek to adapt to complexity through functions such as sensemaking, coordinating, and re-planning. Technologies can augment human cognitive abilities for managing attention, recalling information, projecting trajectories, and achieving common ground. The ideal healthcare system would integrate technologies in ways that maximize the ability of humans to adapt to complexity through coordinating and synchronizing activities, and help people anticipate surprise and error – while preserving the clinical experience among clinicians and patients. This paper reports on our effort to explore the macrocognitive work undertaken at a major healthcare network in the United States. Our team conducted 60 cognitive interviews across seven facilities, covering inpatient, outpatient and community-based settings. We report on our approach based in methods of Cognitive Task Analysis. The approach was simultaneously structured and adaptable, and was therefore well suited for exploratory data collection, as it permitted adjustments to the data collection strategy across a wide spectrum of performers, experience-levels, and work contexts. We review our data collection, analysis and representation methodology, and the seeds for design guidelines for clinical decision support that resulted from the effort.

Keywords: Clinical Decision Support, Macrocognition, Cognitive Task Analysis, Applied Concept Mapping

INTRODUCTION

Modern healthcare can be described as a macrocognitive work system. In such systems people seek to adapt to complexity through functions such as sensemaking, coordinating, and re-planning (Hoffman et al., 2009). Macrocognitive work may be undertaken individually (e.g., forming mental models about patients, detecting problems), organizationally (coordinating care, maintaining common ground), or at both levels (re-planning, monitoring). Macrocognitive work may be informed and facilitated (but in many cases is hobbled) by technological infrastructure: sensors, data repositories, alarms, and communication tools. Technologies can augment human cognitive abilities for managing attention, recalling information, projecting trajectories, and raising awareness. The ideal macrocognitive *healthcare* system would integrate technologies in ways that maximize the ability of people to adapt to complexity through coordinating and synchronizing activities, and help people anticipate surprise and error

(Woods, 2005) — all while preserving and enhancing the clinical experience between clinicians and patients. In other words, provide true clinical decision *support*.

This paper reports on our effort to explore the macrocognitive work undertaken at a major healthcare network in the United States, in order to jumpstart the delineation of guidelines for the design of clinical decision support. Our effort was part of a larger program to introduce the User-Centered Design process (Weinger, 2013; shown in Figure 1) into the development of clinical decision support capabilities that may be used in the healthcare network we explored, and beyond.

We first describe our interviewees. We then describe our method, data analysis and representation approaches. We close with an overview of the design seeds that are serving as a resource for the development of guidelines for the design of clinical decision support systems.

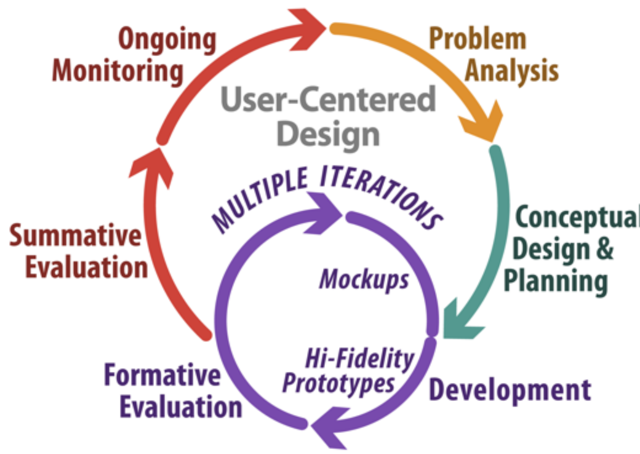

Figure 1: User-Centered Design Process

PARTICIPANTS AND INTERVIEWS

The participants worked in a variety of patient care environments in including the Emergency Department, In-Patient Wards (e.g., Mental Health), Out Patient Primary Care Clinics, and Specialty Clinics. Mr. Moon and Dr. Hoffman, with support from Mrs. Mary Lacroix, conducted 60 interviews across seven sites, as shown in Table 1.

Table 1: Number of Participants by Site, Site Type, and Average Experience Level

Number of Participants	Sites	Site Type	Average Experience Level (in years)
12	Prescott, AZ	Medical Center	23
3	Anthem, AZ	Community –Based Clinic and Telemedicine Hub	
9	San Diego, CA	Medical Center	17
4	Oceanside, CA	Community –Based Clinic	
10	Murfreesboro, TN	Community –Based Clinic and In-Patient Psychiatric Facility	19
7	Nashville, TN	Medical Center	
15	Durham, NC	Medical Center	12

The qualifications of the interviewees also represented a wide spectrum, as shown in Table 2.

Table 2: Number of Participants by Site, Site Type, and Experience Level

Number of Participants	Qualifications
30	MD
20	Nurse
5	Physician's Assistant
5	Other

The duration of the interviews differed, from a minimum of 22 minutes to a maximum of 90. Total interview time amounted to nearly 3,000 minutes (2,949), and the average duration of the interviews was 49 minutes.

METHOD

Cognitive Interviews

Mr. Moon and Dr. Hoffman conducted interviews using structured cognitive interviewing based on their experience at Cognitive Task Analysis (CTA; Crandall, Klein, & Hoffman, 2006). Structured cognitive interviewing uses knowledge elicitation probe questions that are designed to elicit a descriptive account of the cognitive functions and processes required to make decisions and perform complex tasks. The cognitive activities elicited include subtle perceptual judgments, assessment of complex and dynamic situations, decision-making, problem solving, anomaly detection, and planning. Cognitive interviewing uncovers the cues, expectancies, goals, strategies, and typical actions taken by domain practitioners. Importantly, cognitive interviewing focuses on aspects of cognitive work that are influenced and enabled by technologies (e.g. health care software and medical information systems)

We used cognitive interviewing to elicit descriptions of the cognitive and collaborative work of healthcare professionals, the technologies and tools that they use, and difficult cases they have encountered. Our cognitive interviewing approach was both structured and adaptable, and was therefore well suited for exploratory data collection. Given the exploratory goals of our effort, we recognized the need to adjust the interviewing approach and methodology across the spectrum of interviewees, experience-levels, and work contexts. The cognitive interview approach enabled the participants to articulate descriptions of these dimensions, and prompted them to cite examples. Examples of the dimensions of macrocognitive work that we explored are provided in Table 3, along with examples of the questions that we asked.

Table 3: Macrocognitive dimensions of performance, and Examples of Generic Questions

Macrocognitive Dimensions of Performance	Generic Questions
Goals and Constraints	What were you trying to do or accomplish? What was keeping you from achieving this?
Cues and Expectancies	What were you seeing? Hearing? What did you expect to see or hear?
Mental Models and Errors	How did you think it was supposed to work? What might someone else have missed?
Analogues and Typicality	Did this remind you of anything? Was this typical of what you've experienced before?
Situation Assessment and Big Picture	If you had to describe the situation to someone, what would you say? What else were you tracking?
Pressures and Challenges	What was driving the pace or schedule? Why is this so difficult to do?
Aids and Failures	What could have helped you? Did you get what you needed from your equipment?
Options and Rationales	What could you have done? Why did you choose that, and not the others?
Self and Team	What were you monitoring about your performance? Where were the bottlenecks on the team?

In addition to these probing questions, we also drew on "cardinal issues of decision making" for probes based in the literature on judgment and decision-making. The analysis of decision making from the sociotechnical perspective (see Hoffman and Militello, 2008) regards individual decisions as nested in layers of organizational and system complexity. There are a number of "cardinal issues" that are implicated in all decisions (Hoffman, & Yates, 2005; Yates, 1990). These became very salient in the present research, as the interviewees began to "tell stories" about individual decision situations: Why is anything being decided? What are the roles and responsibilities? (Additional Cardinal Issue probes appear below, in Table 4.) Stemming from our very first interviewing results—showing that individual decisions are best understood in their broader organizational and episodic contexts—we used these cardinal issues to extend the set of probes and to form a set of additional categories that were utilized in the analysis of the interview protocols.

Where appropriate and feasible, we also we executed the Critical Decision Method (CDM), which is adapted from the literature on Naturalistic Decision Making (Crandall, Klein, & Hoffman, 2006, p. 69-90). CDM is a structured interviewing protocol for eliciting and organizing stories. Critical Decision Method has been effectively used to elicit stories about specific medical practices, for example emergency physician expertise (Schuber et al., 2013). We found it interesting that the standard initial CDM probe, "Can you tell me of a recent case that was especially difficult in terms of your decision making?", often did not result in a response that suggested that the CDM was appropriate. This finding was, in itself, interesting, as it suggested that in most cases, clinical decision-making was not difficult. Rather, other aspects of their overall work system, to include technologies and tools, were difficult to deal with.

Observations

Contextual Inquiry Observations (CIO) were originally proposed as a data collection technique for this effort. However, cognitive interviews were deemed a more appropriate fit in order to mitigate confidentiality concerns and to enable flexibility in scheduling. Moreover, cognitive interviews took account of the workplaces, artifacts, and strategies that would have been captured using CIO, but also allowed for deep dives into areas of interest. That said, we collected some observations of in situ workplace cognition where it was directly relevant to issues being explored in the cognitive interviews. For example, while interviewing a nurse regarding her role in patient transfers, we observed about five interruptions from colleagues seeking her support – observations that provided invaluable insight into the challenges of information management, collaboration, and interruption for her role.

Data Analysis and Representation

Coding. From the 60 interviews, Mr. Moon and Dr. Hoffman selected a subset for detailed data analysis. All interviews were reviewed and rated with regard to their relative "value" to our purpose. Interviews were rated "1" if their content reflected high value insights by virtue of a unique perspective of the interviewee (e.g., director position, consult provider, new participant role), extended duration, and the depth of perspective of the interviewee into their own and their colleagues' macrocognitive work patterns. Interviews were rated a "2" if their content reflected a previously-explored perspective, abbreviated duration, and/or contained findings that were additive to previously acquired findings. Interviews for which Value=1 were analyzed using two widely-used and complimentary data analysis techniques: Decision Requirements Tables (DRTs) and Concept Maps (Cmaps). Both methods enable data organization, and provide a descriptive analysis of the interview data. These are described below.

In addition to the DRTs and Cmaps, we iteratively developed a macrocognitive work coding scheme. Starting from a notional scheme based in prior research, the Cardinal Issues of Decision Making, and our knowledge of Cognitive Systems Engineering (Hoffman, 2012), we generated, then applied and iteratively refined a coding scheme that focused on issues in decisions about patients, and issues in the macrocognitive work. Like all coding schemes, ours was more or less useful, depending on the data collected in any given interview. We offer the scheme in Table 4 for use by other researchers.

Table 4: Final Coding Scheme

Issues in Decisions about Patients		
Need?	Why is anything being decided?	
Who?	What are the roles and responsibilities?	
How?	What is the implementation or method?	
	SIGNS	Cues, patterns
	HEURISTICS	Reasoning Rules
	CLINICAL KNOWLEDGE	Declarative
When?	When is the decision to be made?	
Resources?	What resources are involved, required or limited?	
Options?	What, if any, options are considered?	
	DEFAULT	No other option
Consequences?	Expectations, outcomes, consequences and their values?	
Stakeholders?	Who has to agree or participate?	
Goals?	What is the desired outcome and why is it desired?	
Tradeoffs and Constraints?	What are the tradeoffs or constraints?	

Issues In The Work		
Patient Care Activities		
PC	Patient Care (treatment, medication)	
PT	Patient Tracking	
PCM	Patient Case Management	
Managing		
MOS	Managing or Influencing the Organization or System	
IM	Information or Records Management	
WM	Workload Management (resource limitations, frustrations)	
RM	Risk Management (risk avoidance)	
Knowledge Requirements		
OK	Organizational Knowledge	
MSK	Medical-System System Knowledge	
Coordination/Collaboration/Communication		
WOC	WOC+	Within-Organization Negotiation/Collaboration
	WOC-	Problems with or Failures to Collaborate Within the Organization
IS	Information Sharing (Common ground)	
BOC	BOC+	Between-Organization Negotiation/Collaboration
	BOC-	Problems with or Failures to Collaborate Between Organizations
TRAIN	Training Issues/Shortfalls	
Computer Systems		
CSK	Knowledge About the Computer Systems	
U+	Positive comments about usability	
U-	Negative Comments—Unusability	
F	Frustrations	
D	Desirements (Discussed below)	
WA	Work-Around (Discussed below)	

Decision Requirements Tables. The DRT is a data summarization analysis approach that organizes findings into descriptions of the key and supporting decisions, and how they are made (Crandall, Klein, & Hoffman, 2006). The DRT organizes data around the decisions that describe the decision context, considerations and approaches taken by performers. Specifically, the fields of data organization used to analyze interviews are shown in Table 5.

Table 5: Decision Requirements Table Categories

Decision Requirements	Definitions
Decision or Judgment	Decision or judgment under consideration
Second and Third Tier Assessments or Judgments	Supporting assessments or judgments
Challenges or Why Difficult?	Reasons why making the decisions and judgments are challenging or difficult
Factors and Cues	Considerations and inputs for making the decisions and judgments
Information Sources	Sources of input for making the decisions and judgments
Strategies or Rules of Thumb	Individual approaches for making the decisions and judgments
Process	Organizationally constrained approaches for making the decisions and judgments
Products and Treasure Maps	Individually devised tools that support making the decisions and judgments
Common Errors	Mistakes that inexperienced performers might make
Examples	Illustrative examples of the decisions and judgments
Desirements	Tools that might support making the decisions and judgments

We generated a total of 19 DRTs, covering 19 of the Value=1 interviews. The DRTs are too voluminous to show here. Suffice it to say, each DRT provides a detailed analysis and organization of each interview.

Concept Maps. Concept Maps are an original type of meaningful diagram that are used to represent and convey knowledge (Moon, Hoffman, Novak & Canas, 2011). Concept Maps involve labeled nodes and links. The nodes represent concepts, which are enclosed in boxes. The label for most concepts is a word or just a few words, although one can also use symbols. Concepts are related to one another by meaningfully labeled linking lines (Crandall, Klein, & Hoffman, 2006, p. 51). While Cmapping can be used as a knowledge elicitation method, Cmaps are also useful for representing descriptive data derived by using other CTA methods. They can show, at a glance, the domain knowledge, processes, and illustrative quotations. Most importantly, they serve to organize findings in a semi-hierarchical structure, enabling appreciation of the “gist” of the findings. Whereas DRTs provide a highly structured, detailed analysis of decisions in a tabular format, Cmaps provide a graphical depiction of decisions and their contextual constraints and affordances. Additionally, Cmaps can provide a hyperlinked organization of the data, allowing for the demonstration of connectivity between subsets of findings. A full appreciation for the interconnectedness of Cmaps is only possible by viewing the Cmaps in hyperlinked, digital form.

Concept Maps have been used in qualitative healthcare research to, for example, describe expert decision making of anesthesiologists (Weinger, 2013), understand comprehension of patient education (Marchand et al., 2002), and accelerate knowledge acquisition regarding complex medical devices (Barberá-Thomás et al., 2011).

We created seven sets of Cmaps covering 7 interviews (not analyzed using DRTs), totaling 37 Cmaps. The Cmaps included descriptions of timelines and decision points, challenges and design opportunities. Three examples are shown below, in Figures 2 through 4.

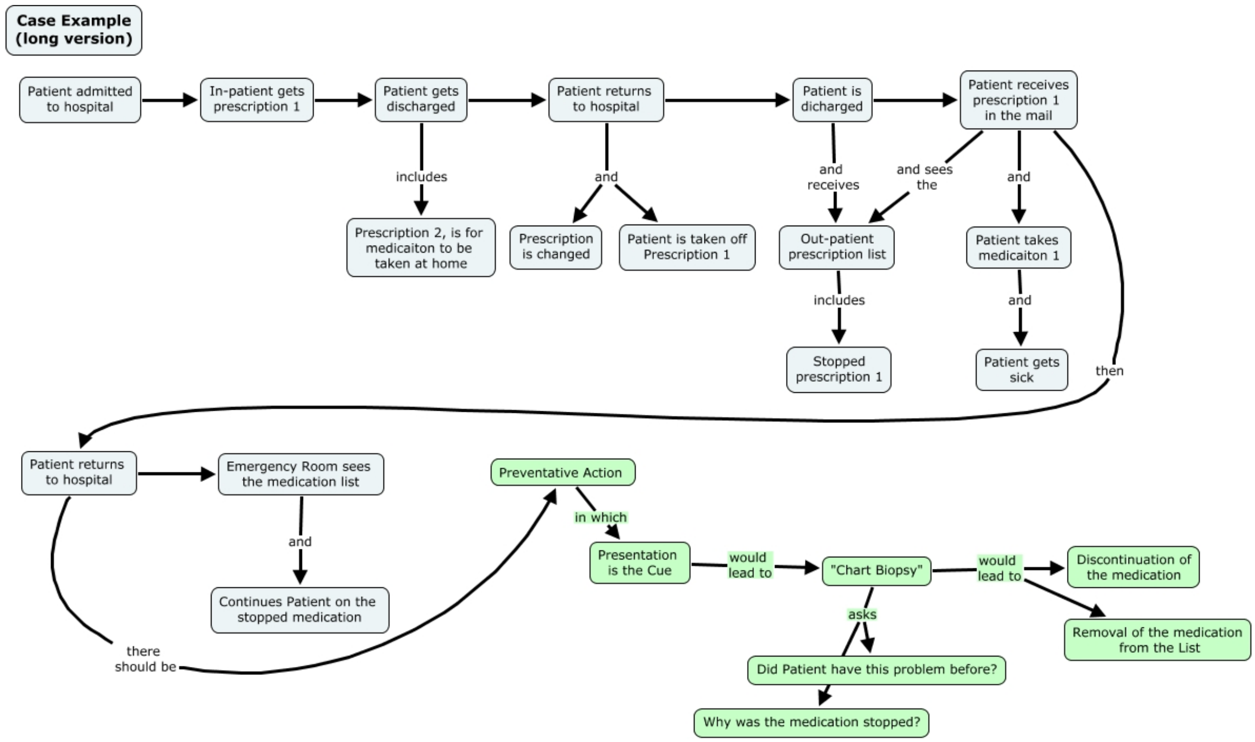

Figure 2. Hybrid Concept Map and Decision Timeline

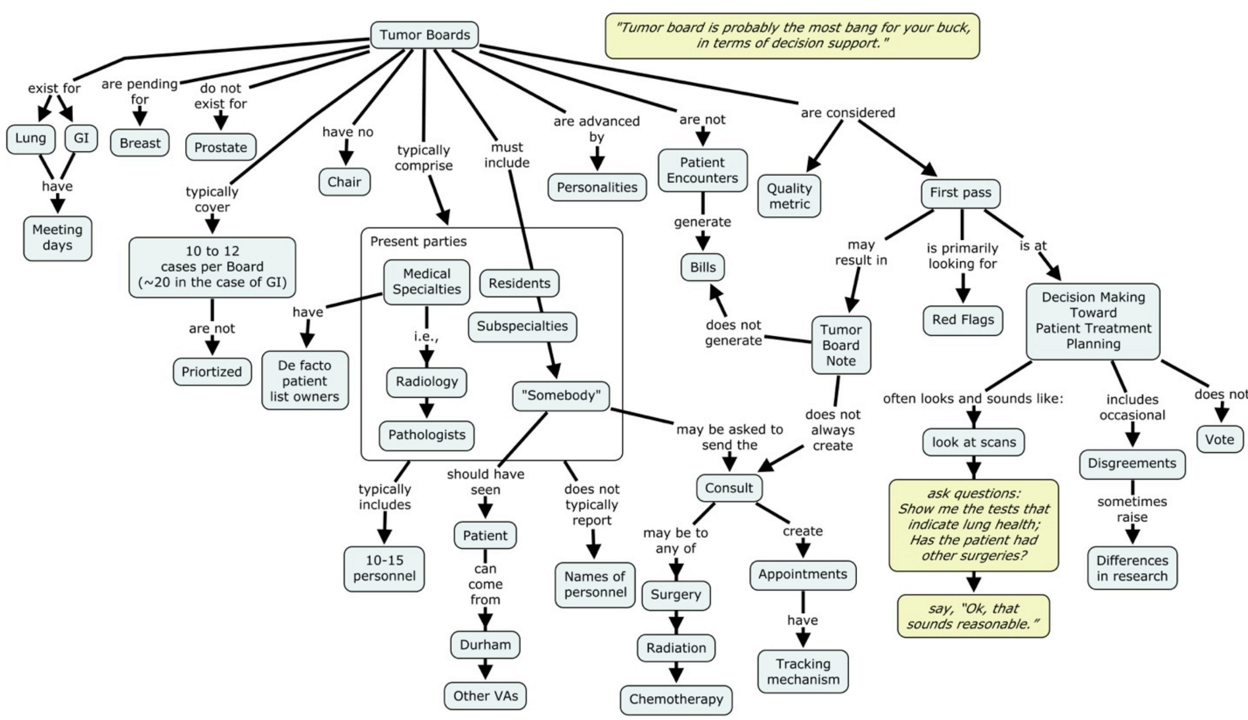

Figure 3. Concept Map describing challenges and design opportunities for Tumor Boards

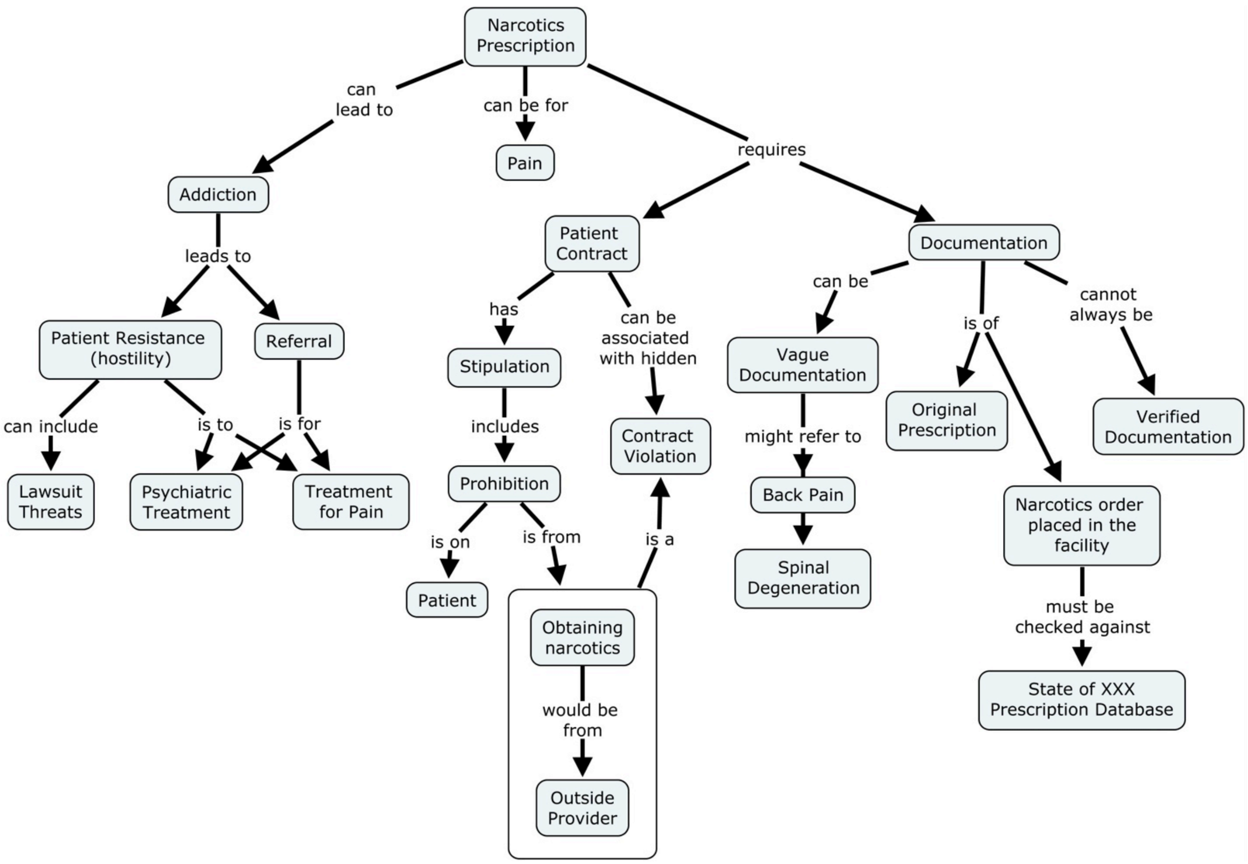

Figure 4. Concept Map describing challenges in narcotics prescribing

MAIN FINDINGS

Contextual Understanding

Macrocognitive Workflows. The DRTs and Cmaps described above provide analyzed and organized descriptions of the interview data, and thereby describe the macrocognitive work explored with individual interviewees.

A second set of Cmaps was also generated to provide a set of "workflows" describing macrocognitive work across interviewees. It is imperative to describe what is meant by "workflows" in the context of our effort. Our use is akin to Gruman et al.'s (2013) concept of "mindflows"— the patterns of thinking that knowledge workers use while doing their work. Our workflows describe a set of macrocognitive areas of performance that comprise work in the healthcare domain, regardless of role. They describe what knowledge is required to conduct the work, the contextual barriers that make the cognitive work difficult, approaches for achieving the cognitive work and managing the cognitive workload, and potential (negative) outcomes of the cognitive work. They provide context for understanding how work is accomplished, and thus can be useful for informing design.

The workflows were not intended as process descriptions for the management of people, information, or processes. Nor are they an indictment on any particular healthcare system, policy, or practice. Rather, they describe—in part through the words of our participants—challenges to cognitive work that are difficult by their nature, but that are sometimes made especially difficult because of organizational requirements and constraints, or that are often made more difficult because of usability and usefulness gaps in the information systems. In many cases, macrocognitive work is challenging because of all three.

Our set of Macrocognitive Workflows is described in Table 6. Two examples are shown in Figures 4 and 5.

Table 6: Macrocognitive Worflows

Macrocognitive Workflows	Description
Assessing	Making sense of the patient's ongoing health in relation to the presenting health concern
Diagnosing	Making sense of the patient's presenting health concern
Caring	Providing the patient with care
Ordering	Ordering products and services in support of diagnosing, assessing and caring
Managing	Managing the patient
Informatics	Making sense of and managing cognitive work

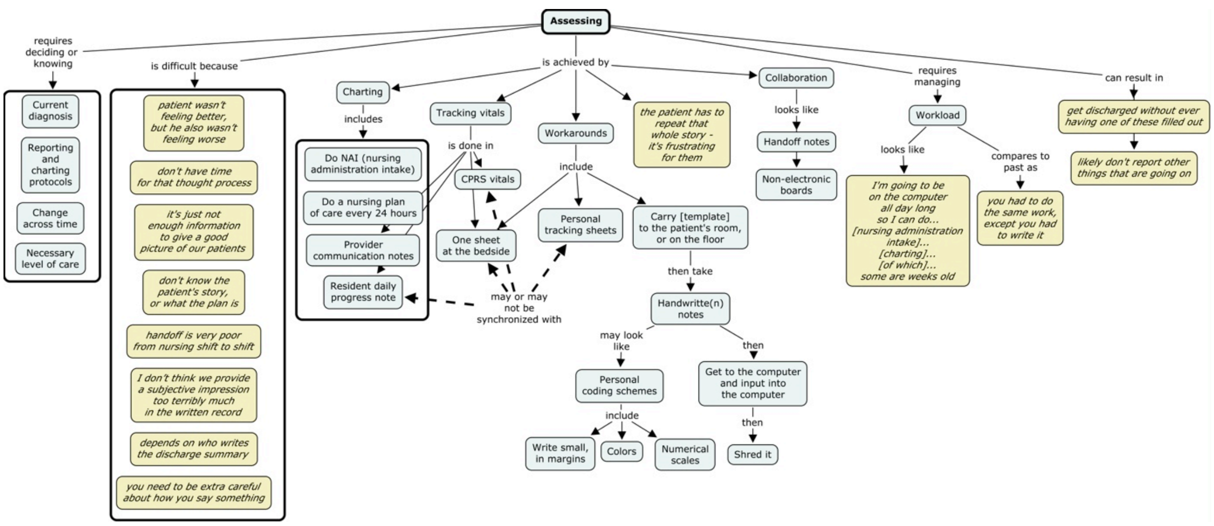

Figure 4. Macrocognitive Workflow - Assessing

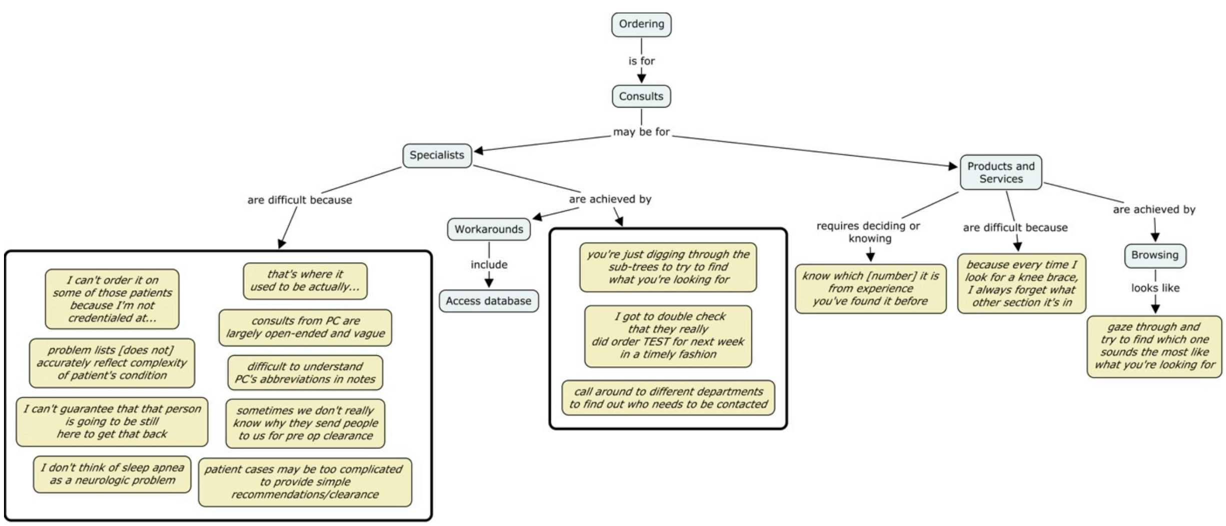

Figure 5. Macrocognitive Workflow - Diagnosing

Stories. The challenges of implementing CDM were noted above. We were able to execute a complete CDM protocol in 10 of the interviews. Thus, the dataset includes 10 detailed stories of clinical decision making across several of the workflows. The stories are too lengthy to show here. Example topics are shown in Table 7.

Table 7: Critical Decision Method Stories

Macrocognitive Workflows	Story
Assessing & Diagnosing	Discovery of previously undiagnosed tuberculosis
Assessing & Diagnosing	Diagnosing an "extended belly"
Assessing & Ordering	Identifying potential narcotics misuse
Assessing & Caring	Challenges in a pulmonary presurgical consultation
Assessing & Caring	Admission to psychiatric inpatient care
Diagnosing & Caring	Missed lab alert resulting in delayed diagnosis of prostate cancer
Managing	Complex patient transfer involving stroke patient

Desirements, Workarounds, Kludges, and Make-work. The cognitive interviews enabled close inspection of macrocognitive work, including work that involves reliance on computer systems. Naturally, the interviews touched on Participants' desirements for new technologies. Desirements are functionalities that support the macrocognitive work, have not been incorporated in a system build or deployment, and represent important operational capabilities. Hence, desirements are not the same as "requirements" (see Hoffman and McCloskey, 2013). In addition to learning what capabilities and functionalities providers would want in their technologies, we also learned a great deal about the workarounds, kludges and make-work they had developed in order to achieve their goals using the systems that they had at their disposal. Whereas workarounds are procedural deviations that must be implemented to circumvent or compensate for a design flaw, a kludge is a system made of components that are poorly matched or were originally intended for some other use (Koopman and Hoffman, 2003). Make-work is repetitive, boring, time-consuming activities that someone must engage in to accomplish something that could not be accomplished using a shortcut, or that one should be able to easily accomplish but cannot. Our analysis and representation products are replete with examples of commentary about these kinds of design issues.

Decision Support Seeds

Patterson et al. (2001) conceptualized design seeds as a modular strategy for aiding performers around a domain-specific leverage point that is expected to usefully support performance—in contrast to traditional systems engineering approaches. Design seeds can be derived from an exploration of macrocognitive work, individually evaluated for their usefulness, and iterated through the User-Centered Design process.

From our exploration, we derived a set of decision support seeds. The seeds were primarily generated from interview data where interviewees expressed desirements for new or evolved support features, and workarounds, kludges and make-work. Seeds were also abstracted from the decision requirements, in particular the challenges, information requirements, strategies and common errors expressed in the DRTs, Concept Maps, and Macrocognitive Workflows. We organized the seeds mostly by the Macrocognitive Workflows, shown in Table 8, below.

We do not believe our seeds comprise a comprehensive set. While they are as broad as the range of experience of our participants, they are only as deep as the experiences we discussed in our limited time with them. Since our aims were broad and exploratory, we did not deep dive into any particular experience bases. The seeds are also limited by our ability to abstract design ideas from concrete experience—additional sweeps through the interviews would likely yield additional seeds. Moreover, our design seeds are not intended to provide specific guidance for any particular type of system, technology or application. Rather, they served the purpose of advancing our exploratory goal, while suggesting directions to designers focusing on designing decision support the Macrocognitive Workflows.

In particular, we believe that several of the findings offer are interesting, generally novel findings that have not been discussed in the literature. These are highlighted in bold in Table 8. We suggest these seeds may offer innovative directions for design that otherwise may not be considered. Notably, these seeds offer support for coordinating and synchronizing activities, and helping people anticipate surprise and error. Uncovering these sorts of seeds strengthens the validity of our structured yet adaptable approach; iterative design and favorable evaluation of them would bolster the utility of the User-Centered Design approach.

Table 8: Decision Support Seeds

Workflow	Sub-Issue	Decision support concept
Assessing	Reporting and Charting	Persistently report vitals to all caretakers
		Provide temporal visualization of vital signs
		Enable users to write about their patients using features available in word processing and handwriting
		Enable users to record (or "chart") using portable devices
		Enable users to know when other users are working in a record
		Enable temporal tracking of patient affect
Diagnosing		Enable enhanced problem list management, to include editing, prioritizing, sharing, and searching
		Provide awareness of the volume of a chart to provide awareness of extent of care
		Enable context sensitivity for clinical reminders
Caring	Medications	Enable now/one-time dose reporting to account for interruptions in medication delivery
Ordering	Laboratory	Provide priority alerting for nonroutine and long duration tests, and abnormal results
		Present available results in obvious ways
		Provide trend analyses of laboratory results
		Enable user preferences for alert previews, grouping and categorizing
		Refine selection options for setting urgency and action-needed notifications
		Synchronize confirmation of order fulfillment across users
	Medications	Enable redundant, electronic medication registration history
		Integrate and update medication change information (e.g., formulary changes)
		Provide orderer with explicit and transparent reasoning for potential denial, prior to submission of order, and allow opportunity for the orderer to state case for approval
		Provide context sensitivity and prioritization for presentation of drug interaction warnings
	Consults	Autopopulate available data fields
		Enhance capability to provide contextual information by orderer
Managing	Servicing and Transferring	***Provide knowledge and status of available services within and across facilities***
		Enable electronic record and image sharing across facilities
	Tracking	Support patient search through uniform registration conventions
		Inform providers when a patient has transferred primary care to another provider
	Searching	Provide preview of patient search results
	Scheduling	Enable simplified return visit scheduling
Informatics		Enable users to extract data that is useful for analyzing the performance and quality of their treatments
		Enable calculations and tallies against templated data fields
		Enable sharing of Standard Operating Procedures across facilities
Cross-issue		Enable users to create templates to support their own information gathering requirements
		Enable users to share and combine templates and template sections
	Care plan and status	Enable an at-a-glance, dashboard representation of care plan, patient status, and care progress that is synchronized across users

<u>Guidelines for Clinical Decision Support (CDS)</u>. Our collective effort is serving as a key resource for the development of guidelines for the design of CDS applications. Additional sources include Osheroff et al. (2012). Dr.

Miller has prepared draft guidelines, which are serving as the basis for designing, evaluating, and iterating a set of CDS interventions (Miller, 2014). Putting the User Centered Design Cycle through its paces in this manner will enable further refinement of the guidelines. Ultimately, the guidelines will provide practical guidance enhancing the User Centered Design, particularly during the design and evaluation phases.

CONCLUSIONS

Modern healthcare must balance three things: (1)the focus on safety and reliability (2) the introduction of software-based systems and (3) the need to mitigate disruptions to the clinical experience. To achieve this balance, the design of healthcare information systems and clinical decision support systems must include an appreciation of macrocognitive work in context. It is only through such an understanding the designers can hope to create *truly* supportive clinical decision aids, and provide access to the right information, at the right time, for the right people. Cognitive interviewing is necessary as a window onto practitioners' macrocognition, their desirements, and the decision challenges they face. Decision Requirements Tables and Concept Maps are useful tools for analyzing and organizing qualitative data that informs design and helps to establish guidelines for effective designs. We encourage the extension of our approaches, design seeds, and further analysis of the guidelines this project helped to shape.

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