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14. ABSTRACT

The Cooperative Communication System (CCS) is intended to improve patient care by supporting Burn ICU clinical decision making through computer-based decision and communication support. This project is divided into three phases: foundation research, prototype development, and prototype assessment. In Phase 1, we collected and analyzed data on clinician patient care and unit management, producing 39 requirements for the CCS. During Phase 2, we developed user-oriented use cases and information design prototypes based on Phase 1 findings. We also developed a programming prototype that translates the information design's organization and information into an interactive interface and reviewed it in January 2015 with 26 members of the USAISR clinical staff. The ARA machine learning team has developed approaches that survey patient data to detect patterns and trends that are clinically relevant. We are developing plans to evaluate software prototype usability at the USAISR, which is scheduled for early November. Army and Institutional Review Board requirements compliance has delayed project progress, and we have requested a no-cost extension through May 2016.

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1. Introduction and Project Overview

The U.S. Department of Defense maintains one of the largest healthcare networks in the world, supporting in-patient and out-patient care not just for the active military, but their families, reserve forces, veterans, and even civilians local to various military treatment facilities (MTF). As such, each MTF experiences a wide variety of patients and clinical requirements.

Burn Intensive Care Unit (ICU) patients present healthcare teams with unique challenges and complex combinations of life-threatening injuries and illnesses. Care for these patients is necessarily multidisciplinary. Care providers across professions must collaborate to make effective decisions, develop treatment plans, assess patient progress, and refine management over time. Management decisions, though, are only as good as the information available when they are made. For this reason, the Institute of Medicine recommended improving access to accurate, timely information, and making relevant information available at the point of patient care to improve patient safety. Despite advances in computer systems and knowledge resources, communication failures between resources and healthcare providers continue to cause the majority of misadventures in healthcare delivery. Critical information for decision making remains difficult to access and deliver and is often missing at decisive moments.

Healthcare providers in the Burn ICU (BICU) environment amount to a joint cognitive system that can be studied, modeled, and assisted through scientific methods and information technology to improve decision making and, thus, improve patient care. The daily work of the clinician requires knowledge representations as part of this joint cognitive system to serve as a map for the ever-changing environment of work that must be successfully navigated.

As we envision it, the Cooperative Communication System (CCS) is part of a joint cognitive system that allows the healthcare team to remain connected to an individual patient and to each other across time and space as the team delivers patient care. As such, it can keep providers informed of a patient's status, of other healthcare providers' activity related to each patient, and of potential discrepancies among healthcare providers' broadly defined, patient driven goals, specifically defined objectives, and individually focused tasks. This type of networked system could also extend beyond the fixed walls of a hospital to incorporate pre-hospital, contingency operations, and theater evacuations. For example, when a soldier is injured, a networked communication system could immediately start relaying information to a Forward Surgical Team or Combat Support Hospital to keep the receiving healthcare team apprised of the patient's status so that they can adequately prepare. Handoff on arrival is then facilitated. The enhanced communication afforded by this system will decrease complications which will directly improve patient outcomes.

In addition to the improved communication among providers, this project explores the potential to provide relevant information to support clinician decision making. The potential exists for the use of artificial intelligence (AI) algorithms to display pertinent, prioritized information to a specific healthcare provider to support their current task. As more data becomes available to the AI system during patient care, the CCS will continuously (in real time) improve the availability and accuracy of the information displayed. This type of decision support should aid care providers from novice to experienced clinician by expanding support for decision making. Through decision support, patients might receive more accurate and timely diagnoses, more timely and appropriate testing, and best evidence-based care. The time lag from "bench-to-bedside" evidence-based interventions can be markedly reduced. Through better communication among the healthcare team and by dramatically enhancing the availability of salient information necessary to make decisions, we expect the CCS to reduce complications and costs and to improve overall patient outcomes.

The goals of this project include:

- PHASE 1: Describe patient progress through burn intensive care to create a shared mental model for clinicians of all specialties;
- PHASE 1: Provide a thorough account of the clinician cognitive work (i.e., work flow and decision requirements) for clinical work in the Burn ICU, including accountability of all pertinent recorded and non-recorded data;
- PHASE 1: Present design requirements for the information, the underlying cognitive networking rules, and the display format of an IT-based cognitive aid for healthcare delivery (the Cooperative Communication System);
- PHASE 1: Derive quantitative evaluation criteria for comparative evaluation of clinical support tools;
- PHASE 2: Present a prototype CCS design for testing and implementation in the USAISR Burn ICU;
- PHASE 3: Develop a test bed based on the clinical environment for Test and Evaluation of the CCS and other clinical support tools.

Phase 1 tasks developed a valid understanding of the Burn ICU work domain, and individual and group cognitive work:

- *Task 1.1: Initial Observation of the Burn ICU.* Through observation and informal interviews, ARA identifies care activities, workload requirements, decisions in patient care, and the cognitive artifacts clinicians use and created a structured interview guide to drive the work of this phase.
- *Task 1.2*: *CTA Structured Interviews and Observation.* ARA conducted CTA based on the observations from Task 1 and the interview guide. The structured interviews with clinicians identified the processes, tools and cognitive artifacts, and data they use during their patient care activities.
- *Task 1.3*: *Integrated Data Analysis and Model Development*. ARA analyzed the data gathered in Tasks 1 and 2 and build valid representations of the cognitive work.
- *Task 1.4*: *Decision Model and Design Requirements.* ARA developed specific decision requirements that are necessary for care management in the Burn ICU.

Phase 2 tasks used Phase 1's research to develop design requirements for the IT-based cognitive aid, evaluation criteria, and a functional prototype of the CCS design:

- *Task 2.1*: *Scoping and Planning*. ARA and USAISR translated the Phase 1 findings into detailed software requirements.
- *Task 2.2*: *Analysis*. The ARA and USAISR analyzed software requirements and developed preliminary designs focused on the user interfaces and main architectural features.
- *Task 2.3*: *Design Phase.* ARA, and USAISR developed the software designs including coding and communication details.
- *Task 2.4*: *Implementation, Integration and Testing*. ARA and USAISR are performing routine testing throughout the software coding effort.

Phase 3 tasks are using results from Phase 2 to complete and evaluate the CCS prototype.

- *Task 3.1: Participatory Design.* ARA and USAISR developed initial notions for scenarios.
- *Task 3.2: Evaluation Testing.* ARA will plan outcome-oriented evaluation to assess the prototype CCS concepts.
- *Task 3.4: Usability Assessment.* ARA and USAISR will determine the effectiveness of an interactive version of the laboratory scenarios, and test versions of the CCS as they are developed.
- *Task 3.3: Validation Testing.* ARA and USAISR will verify that the laboratory scenarios fit with clinician task performance in actual use in the field.
- *Task 3.5: CCS Clinical Implementation and Transition.* ARA and USAISR will identify the transition requirements and finalize the technology transition plan for the completed prototype CCS

a. Team Management

The ARA team assumed project responsibilities following the termination of SSCI as subcontractor at the end of Phase 2. The ARA Machine Learning (ML) team has developed a series of algorithms that have scaled successfully from a 16-patient test data set to a far more substantial 2-year patient data set. The CCS ML software can now identify patterns that clinicians would otherwise be unable to detect, such as variable trends (e.g., blood pressure over time), prior patients who have similar conditions, and clinician notation from prior cases that could inform current diagnoses and treatments.

Dr. Nemeth retained Sarah Murray, RN, to serve as Research Nurse for the remainder of the project. Ms. Murray is currently pursuing her doctorate and is exceptionally qualified to serve in that role. Dr. Nemeth retained independent consultant, Beth Crandall, to address clinician decision making, which is an essential part of the CCS usability and validation assessment. Ms. Crandall has over 30 years of experience in decision making at the individual and team level, in a range of applications including healthcare.

b. Development

The ARA team distributed a survey in December 2014 to prioritize the problem statements that were identified during Phase 1 data collection and analysis (Nemeth et al., 2014). Twenty-five BICU staff members completed the survey in which they rated their level of agreement with the challenges that the problem statements described. Results were aggregated into a Validation Memo (Appendix H) which enabled the team to determine the relative importance of different CCS modules or widgets to optimize development priorities.

The team is using the Jira database to ensure Phase 1 and 2 requirements are managed effectively through the remaining portion of the development process. The use of Jira also supports software team development sprints.

In January, the USAISR indicated that each agile development widget (the seven core functions) would need its own process improvement (PI) study if it was to be supported by their IT department. As a result, the team wrote and revised the set of PI forms. In light of JPC-1 interpretation of software development regulations, the PI process was discontinued. Instead, the team developed, and the IRB approved, the Laboratory Protocol that is now in use.

c. Prototype Evaluation

During Phase 2, the ARA research team reviewed initial versions of the CCS information design with BICU clinicians. Team members also completed 39 requirements (Appendix I) for the CCS system as well as a series of use cases that they provided to the software team to guide prototype development.

The ARA team collaborated with the USAISR staff to develop a set of scenarios and use cases in preparation for an evaluation of the system January 5-9, 2015 with a representative sample of BICU clinicians. Shortly before the planned evaluation, USAISR considered a usability study to be premature due to the number of data elements that still needed to be mapped from the Essentris database to the CCS prototype. As an alternative, the ARA team installed the prototype onto the development environment on January 5th, making an informal review possible with 26 clinicians and the USAISR decision support team. Results were used to guide the next generation of the CCS prototype (See Appendices E, F, G, and H).

The ARA team assembled material on clinician decision making and interface evaluation including Anders et al., 2012; Brooke, 1996; Lowry et al., 2002; Nielsen, 1994; and Wiggins & Cox, 2010 to support development of plans for CCS prototype assessment.

d. User Interface

The primary user interface (UI) development activities in Phase 3 were to implement a configurable Patient View, Orders View, and Messaging View. These tasks were all guided by the requirements (Appendix I) resulting from research performed in Phase 1 and the prototype evaluation at the end of Phase 2.

In Phase 3, the team shifted to an Agile Development approach. The primary driver behind the shift to Agile was to get feedback sooner and more often. The team accomplished this by breaking development tasks into short two to three week “sprints” and demonstrating new functionality to the ARA cognitive team and USAISR clinical team after every few sprints. This approach improved communication among the distributed team members by having everyone regularly review the current state of the software on and provide comments on how the development team should prioritize tasking.

The user interface is organized in parent-child format, displaying tabs that are visible in the patient view that can be used to open more detailed displays. Tabs are organized according to physiologic systems. Users can also create new tabs.. Making the CCS seven core functions individual software elements, or “widgets,” affords the opportunity to configure displays according to individual preference.

Patient View. One of the findings from the Phase 2 evaluation was that clinicians needed the ability to dynamically configure their view of the electronic health record (EHR) (Appendix H). Current systems offer a “one-size-fits-all” approach to viewing the EHR, independent of the patient’s condition and the clinician’s line of inquiry. The Phase 2 implementation of the Patient View reflected the data requirements (Appendix I) of the Phase 1 research but presented information in a static format (Figure 1). In Phase 3 we leveraged the Phase 1 research which produced the top-level information design prototype, and added the ability for clinicians to customize their views. We used the information design as the “base-case” for the type of views that needed to be configured.

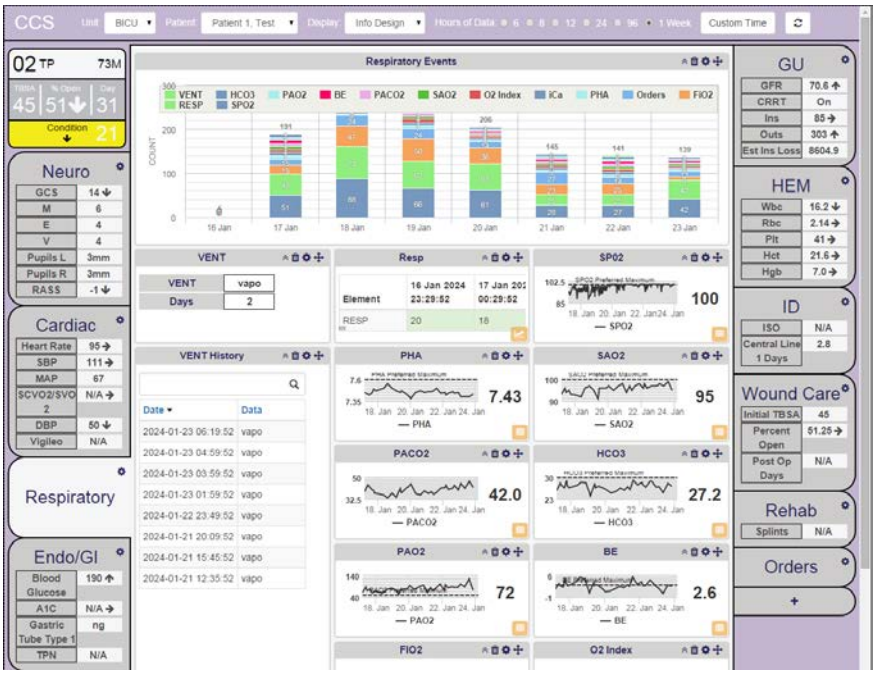

Figure 1. Patient View

Patient Identifier Widget. The Patient Identifier Widget, which appears in the upper left corner of the patient view, now indicates if the patient has a Do Not Resuscitate (DNR) order. In addition, we have connected the Condition field to the Machine Learning software output. The updated widget is shown in Figure 2.

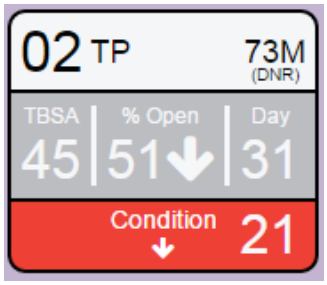

Figure 2. Patient Identifier Widget

Orders Widget. The methodology for handling Orders underwent dramatic changes in Phase 3. In Phase 2, we combined several functions into the Charge Nurse Rounds (CRN) View, including Orders, Tasks, and a Checklist. During the Phase 2 evaluation, the team received feedback that these functions would be better developed and tested as independent widgets. The idea behind this decision was that by approaching each of these capabilities independently, the team would be able rapidly iterate and refine each capability without trying to tackle too much at once. This decision coincided with the push to do more Agile development and more customer demos. The first capability of the former Rounds CRN view which was developed was the Orders View.

The Orders View is implemented as a Widget type which can be placed anywhere on the Patient View. We currently have a dedicated Orders Tab which prominently features the Orders Widget. The Orders Widget provides a tabular view of all of the patient's orders. The widget uses the time querying functionality resident in the Patient View to allow a clinician to view current orders or to scroll back in time to view historic orders.

Several features of the Orders View make it unique in comparison to traditional EHR methods of viewing Orders and also tie into the overall theme of configurability. Specifically, clinicians can choose to filter the orders that are viewed by Type and can also define free-text search terms which can further filter the results. This capability allows a clinician to place an Orders Widget on a Cardiac View that only displays cardiac related medications, or place an Orders Widget on a Wound Care view that only shows orders for wound treatment. The theme of putting configuration options into the UI and letting clinicians determine what data to show and where to show it was key to development of the Orders View.

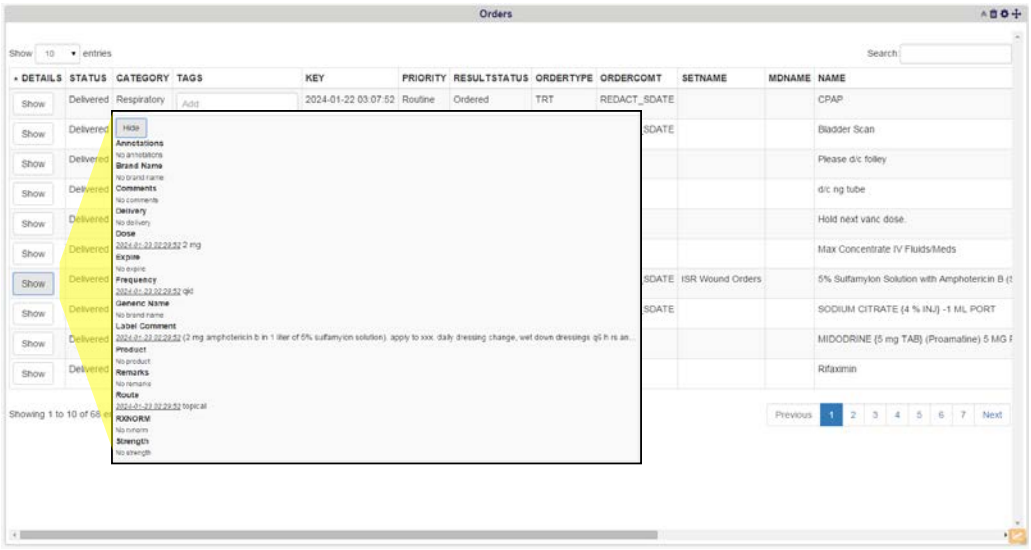

Figure 3. Orders View showing Order Details.

Messaging View. Recent activity in Phase 3 has focused on development of the Messaging View in CCS. An initial Messaging View was developed in Phase 2 and was evaluated at USAISR in Jan 2015. The Phase 2 Messaging View provided per patient "channels" where staff members could "chat" about a patient. While this approach offered flexibility, the Phase 2 evaluation showed that it needed more definition on how messaging would be managed in the BICU. AISR provided a rule set that the team used to guide wireframe development.

After developing the Phase 3 messaging requirements, the user interface team produced a set of wireframe design mockups to illustrate our intended approach to meet the requirements. An example of a messaging wireframe design mockup is shown in Figure 4. Current activity is focused on developing the functional messaging view in accordance with wireframe mockups.

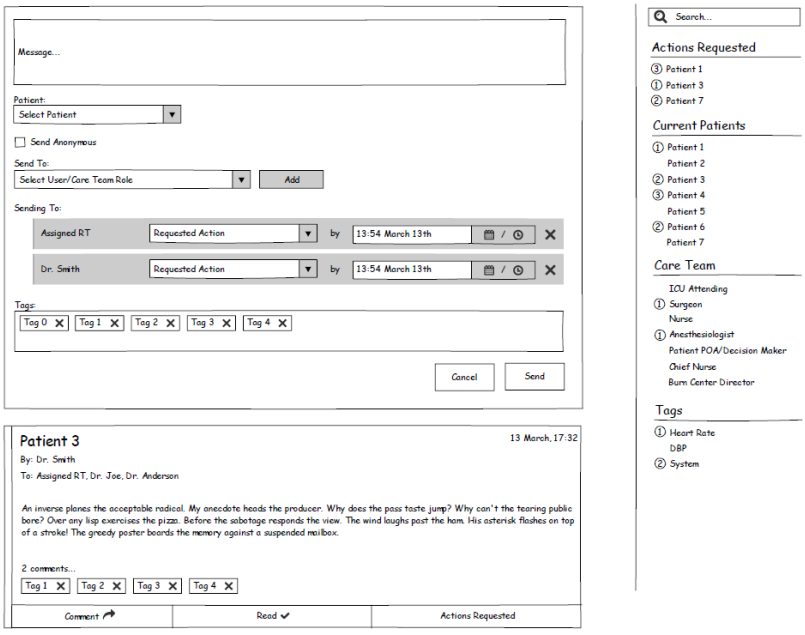

Figure 4. Messaging wireframe.

e. Machine Learning

Productive work by ARA ML experts in our Raleigh, NC office, and ML task performance in Phase 3 has progressed at a more rapid pace since ARA assumed this task and is now on track. In this section, we provide an overview of how ARA wrapped up Phase 2 with SSCI and how the ARA ML team progressed in Phase 3 starting in February of 2015.

Phase 2 Wrap Up

In October 2014, members of the software development team travelled to USAISR to complete all in-processing requirements and to install current prototype software within the USAISR's development network. Members from both ARA and SSCI in-processed to obtain access to the USAISR development network – a virtual machine configured to mimic aspects of the production system. During this October site visit, we installed early versions of both the UI and ML components within the USAISR development network and configured the software to point to a substitute Essentris database. This was a major milestone for the software development effort.

As Phase 2 concluded, the ARA team determined that the core technology the prior ML subcontractor, SSCI, had developed was not sufficient to satisfy the CCS requirements. The level of additional research necessary to bring the system based on SSCI's underlying technology exceeded the remaining budget and timing for the project. Consequently, the PI assembled a team of highly qualified ML professionals in ARA and tasked them with assuming responsibility for CCS ML in Phase 3. ARA conferred with the COR and with permission submitted a modification to transfer funds to ARA to support ML work. No SSCI software or designs were transferred to the ARA team.

Phase 3 Effort

In February 2015, the ARA ML team assumed project responsibilities following the termination of SSCI as subcontractor. The ARA ML team is now led by Chris Argenta and maintained the same goals for Phase 3 as initially planned. We proceeded to redesign and develop the ML solution using a different set of core technologies that we believe better model the temporal nature of the data and provides improved visibility into the factors contributing to analytic results. This approach proved to be more insightful and productive. During an April 2015 site visit, ARA in-processed 2 ML developers at USAISR, installed and executed their initial code successfully in the USAISR development environment, and provided presentations on early results that exceeded the Phase 2 software and incorporated twice the variables.

In the following sections, we outline our technical approach and progress made to date, our goal use-cases, and our ML team.

Phase 3 Technical Approach

The Phase 3 CCS ML team's approach differs significantly from that of Phase 2 approach because it recognizes and addresses to major technical challenges as part of the code solution:

1. Patients have a wide diversity of time-series data with sparse and uncertain entries representing a combination of both medical interventions and patient responses. This complexity mandates a solution that incorporates temporal models showing progressions of care and sensor readings. This is because instantaneous data cannot accurately characterize the patient care trajectories needed to match similar patients' care plans or provide cases representing possible future states for consideration.
2. The operations must provide quick and accurate responses at scale. The objective system will consider many patients dating back many years, some of which will have records spanning long time periods potentially including multiple (potentially even independent) treatments. The scale of the problem mandates a solution that will handle the large existing database; accept, integrate/index, and classify new data from ongoing patient care; and quickly identify best matches to support interactive queries from clinicians.

Our new ML approach includes a new software architecture that can be more closely integrated with the CCS system and will significantly improve data processing performance (Figure 5). One reason for this is that this approach synchronizes and stages data by copying it from Essentris and storing cleaned and formatted data in a CCS database where we can access data in more efficient ways. This approach maintains the restriction that CCS does not write or change any data in Essentris, while handling the fact that data in Essentris is not structured or curated to support complex analytic processing.

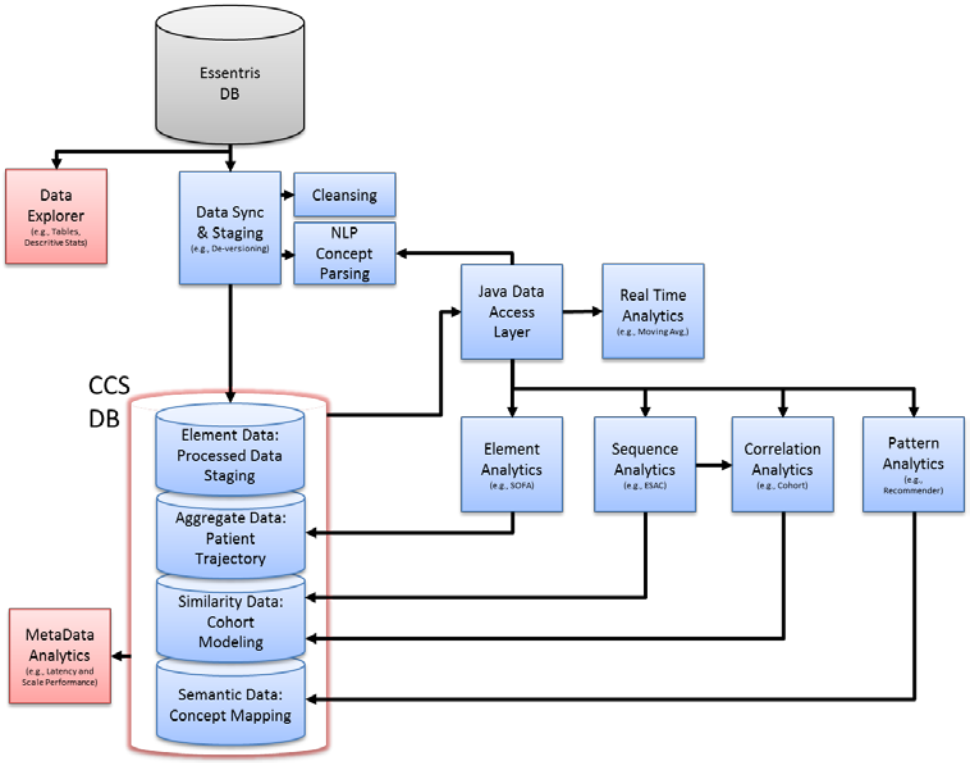

Figure 5. Machine learning architecture.

Our approach combines ML analytics to analyze clinical records, develop models of patient/clinician interactions, and provide clinicians with decision-support information using the CCS UI. Eight key components of the system are:

1.	Data Explorer	This tool analyzes the Essentris database schema and contents. To aid in exploration of the data it extracts summary metadata. It outputs a .csv file containing meta data without personally identifying information.
2.	Data Sync, & Staging	This tool synchronizes, cleans, and pre-processes key data from patient records for staging for analytics. It reads from Essentris database, writes to the CCS database. It integrates with modules for data cleansing and parsing of notes tables for Natural Language Processing (NLP) to extract key concepts relevant to patients at a particular time.
3.	NLP Concept Parsing	This component parses free text notes entries in the patient data and extracts references to identified problem-related concepts and generates event logs in the CCS database to capture these. We have analyzed the SNOMED CT ontology, and started on ICD-9/10.
4.	Java Data Access Layer	This component provides structured access to data repositories. Because the data in the CCS database has been cleaned in the staging database this process is fast and reliable. Additionally, no custom written queries are required, so it changes to database tables (such as versioning in Essentris is data driven and does not require software changes).
5.	Real Time Analytics	These components are used to directly support interactive features of the UI, where analytic capabilities (e.g., moving and windowed averages) and running of models against active patient data (e.g., extracting clinically relevant similarities from cohort recommendations).
6.	Element Analytics	These components read in-time series patient data and write out aggregations, interpolations, and direct data analytic functions. At this time, ARA has implemented modified SOFA and POIP-based trajectories.

7.	Sequence Analytics	These components use ML to model temporal sequences where the ordering and relationship of events is critical to interpretation and similarity measures. We are integrating ARA's unique Event Sequence Alignment and Clustering (ESAC) for this process, and will be extending it going forward.
8.	Similarity Analytics	These components compute correlations between multiple factors in the data (including aggregated data) to learn models for cohort similarity and probabilistically predict future trajectories based on historical precedence. We have developed three models for similarity with temporal windowing. These include: statistical T-test models (tests if means and variance are similar), slope/trend analyses (tests if changes are trending similarly), and integral differencing (tests for space between curves).
9.	Pattern Analytics	These components bridge the semantic meaning of various data elements to identify domain-knowledge-based similarities where content-only comparisons fail. We will use these and Natural Language Processing (NLP) technologies to identify key concepts from clinician notes and attempt to mode the relationship between their usage and the underlying data, so that we can recommend concepts that may be represented in unlabeled data.
10.	Metadata Analytics	These components instrument the CCS ML system so that we can measure performance, identify issues, and better estimate scalability and stability.

Use Cases

During Phase 3 we are addressing three key use cases:

Use Case #1: Identify possible discrepant clinician actions according to patient current condition and predicted trajectory.

Addressing this Use Case requires analyzing historic patient records, developing models for quickly finding cohorts for the current active patient and determining how patient and clinician events contribute to similarities in trajectories and probabilistic outcomes.

Tasks include: Constructing current patient model, constructing relevant and concise patient models and similarity measures, learning models for most applicable cohort list, evaluating the cohort composition, and develop/evaluate recommender for orders.

Progress to date: We have three cohort similarity models that have been run on test and USAISR data, and a tool to visualize and explore similarities. This is a development tool that we do not expect clinician to use. We are currently using over 50 variables (not a hard limit) and processing order records. We will be evaluating weightings and ensemble methods going forward. We have performed sensitivity analysis on window size and other factors and have developed a tool that allows us to interact with the similarity data and drill down to raw comparison values; this demonstrates the ability to explain cohort recommendation. Figure 6 shows an example of similarity data (not clinician interface) using the IRB approved (for use outside the USAISR dev network) deceased patient data set.

A similarity matrix graphically shows the relationship between patients by time window. Each patient is shown across the top with each time window, the same is in the vertical (in the same order). Each pixel represents the relationship between the patient/time window on the top and the left, so the diagonal represents self-to-self at the same time. Similarity values are between 0-1 and the pixel color is set on a gradient (lighter is more similar). This representation is useful for seeing general patterns across all patients/times – it is not an end-user view. We are currently computing the similarity using three methods: statistical similarity (appear to come from the same distributions), trend similarity (are they going the same way), and integral similarity (the space between curves if plotted over time) – we have versions of these with different weighting, windowing, and ensemble compositions. One of the challenges we are attempting to address is which combination results in similarities that are clinically interesting.

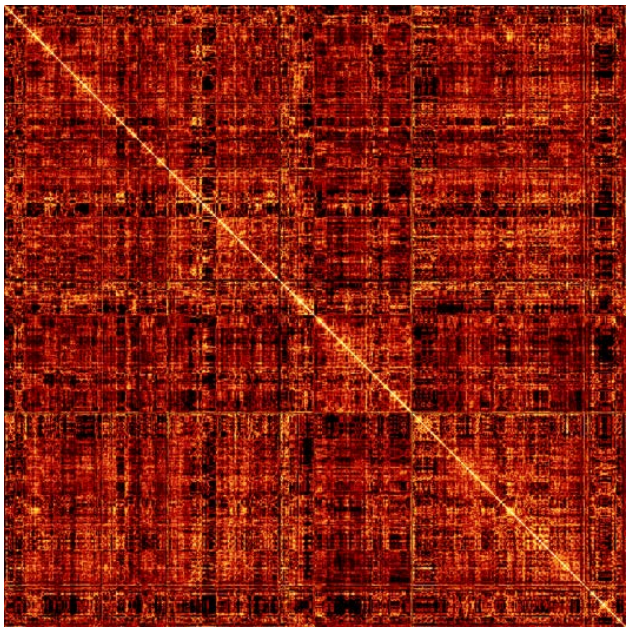

Figure 6. A similarity matrix comparing 23 data elements for 11 deceased patients over 8-hour time windows for the duration of their stay.

Use Case #2: Identify possibly worsening patient trajectory.

Addressing this Use Case requires aggregating patient data and modeling abstract wellness over time. This information is to be used to represent the patient condition in the UI.

Tasks include: Constructing patient and clinical action models, aggregate and quantify condition metrics from patient state, recognize and predict inflection points in condition, and evaluation of predictive analytics.

Progress to date: We have implemented 2 modified versions of existing wellness scoring models and converted them to trajectory measures. We will be using these to help calibrate/verify additional ML-based trajectories that we develop to be more tailored to the Burn ICU context. (i.e., learned from BICU data rather than incorporating methodologies developed for a general population. We can currently display these trajectories (they are stored as aggregated elements in the database) in the customizable view in the CCS UI.

Use Case #3: Problem List Summary and Decision Support.

Addressing this Use Case requires learning models of how measurements map to clinically-relevant concepts, particularly problems that might be present.

During initial investigations into this Use Case for Phase 3, we identified two issues: (1) The UI did not contain a widget for manually labeling problems, and the data set we are permitted to use under IRB protocol would not include active patients with such labels if they existed. (2) There were no encoded problem types in the Essentris database. Instead these data tend to reside in narrative form in clinical notes throughout the database. These discoveries forced us to change how we go about implementing a solution for this Use Case.

Original task included: Modeling “problems” with respect to known data models, editing problem labels/rules, and evaluating problem labeling.

Updated Task includes: Addressing this Use Case requires parsing key terms from natural language notes fields in the database, modeling the co-occurrence of these terms with trends/events in the patient data, and using this model to recommend terms that describe observed patient data dynamics.

Progress to date: We have identified issues that forced us to change the way we address this use case. We have acquired and reviewed the SNOWMED CT taxonomy of terms/concepts and determined that SNOWMED codes are not available in Essentris data. We are in the process of converting the label and description data from SNOWMED into a keyword/concept ontology (that can be fused with others, such as ICD) for relevance computations.

ARA ML Team

The Machine Learning team is working closely with existing team UI Development Team. This provides faster turn-around, reduces confusion, and lowers project and integration risk. The ML Team is co-located with the UI team, uses the same processes and tools, and has the same management chain.

Chris Argenta 20+ years' experience: Intelligence Systems, System M&S, Tactical Communication Management
Expertise includes: Artificial Intelligence, Complex Data/System Analytics
Focus on Project: Task Lead, Sequence and Semantic Modeling
cargenta@ara.com

Bryan Fricke 15+ years' experience: Software Process, Building and Threat Modeling, Analytics
Expertise includes: Modeling and Simulation, Software Development
Focus on Project: Core Data Access and Application of Analytics
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Randall Frank 26+ years' experience: Large Scale Analytics and Visualization
Expertise includes: Biomedical Engineering, Scalable Computing, Mathematical Modeling
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Expertise includes: Mathematical Modeling
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2. Deliverables Status

The deliverables for the CCS project to date are:

1. Approved Human Use Protocol: Final approval completed February 27, 2013, Amended protocol approved April 30, 2013
2. Interview Guide: Developed January 2013, refined May 2013
3. Visit Reports (4):
    a. First site visit March 4-8, 2013
    b. Second site visit May 20-24, 2013
    c. Third site visit July 22-25, 2013
    d. Fourth site visit November 18-22, 2013
4. Initial Software User Interfaces: Delivered January 2014
5. Burn ICU Cognitive Model: Delivered February 2014
6. Phase 1 Final Report: Delivered February 2014
7. Validate User Interfaces with USAISR Users: March 23-28, 2014
8. Finalized User Interfaces for Prototype Development: Delivered April 2014
9. Annual Report: Delivered September, 2014
10. Working Prototype: Started, delivered January 2015

Pending deliverables include:

1. Usability assessment plan and criteria for November 2015, and January 2016 assessments
2. Request for no-cost extension
3. Burn ICU Metrics: Completion extended for Module 2 development 2015

4. Usability Assessment (Rescheduled for November 2015) [pending NCE approval]
5. Validation Assessment (Scheduled for January 2016) [pending NCE approval]
6. Tested prototype and Final Report (Scheduled for May 2016) [pending NCE approval]

The following are planned for Quarter 12 (August 16 – November 15, 2015):

a. Installation of the CCS UI and ML components within the USAISR development environment
b. Complete initial application program interface (API) and development of database from CCS System
c. Complete initial module development of the prototype design including the Editor Architecture, January visit revisions (if applicable) and form refinement
d. Continue to conduct internal tests of initial software prototype design
e. Begin testing scalability of the system
f. Conduct agile development sprints to enable USAISR to socialize new procedures such as scheduling
g. Develop material related to clinician decision making to support October 2015 and January 2016 assessments

The figure below shows the updated project research schedule in Gantt chart format. It has been adjusted from the original submission to account for the development delays associated with IRB Protocol approval and the anticipated No-Cost Extension.

Task #	Task/Phase Name	Deliverable or Milestone	Year 1				Year2				Year 3				NCE		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Phase 1: Cognitive Systems Engineering																	
1	Orientation to ICU Procedures	Structured interview guide															
2	Data Collection	Documented cognitive work in ICU															
3	Data Analysis	Valid descriptive model of the cognitive work															
4	Findings and Design Requirements	Design requirements for the IT-based cognitive aid															
Phase 2: CCS Development																	
1	Scoping and Planning	Critical cognitive requirements and detailed softaware requirements documents															
2	Analysis	Preliminary design covering usability indices and approach to software design															
3	Design	User interfaces mockups and detailed software design description															
4	Implementation, Integration and Testing	Initial prototype IT-based cognitive aid															
5	Acceptance and Release	Final prototype CCS															
Phase 3: Laboratory Testing of the CCS																	
1	Test Environment Setup	Develop controlled test environment and procedures															
2	Pilot Evaluation	Pilot user evaluation of CCS prototpye															
3	Usability	Usability assessment of CCS prototype															
4	Validation	Validation assessment of CCS prototype															
5	Final Deliverable	Tested prototype CCS prototype IT-based cognitive aid															

Figure 7. Updated Tasks and Deliverables Schedule.

The following activities are planned for September 2015-May 2016:

- Evaluation Testing. ARA will plan outcome-oriented evaluation to assess the CCS. (Task 3.2)
- Usability Assessment. ARA and USAISR will test latest version of the CCS for individual use. (Task 3.4)
- Validation Testing. ARA and USAISR will test the latest version of the CCS for team use. (Task 3.3)
- CCS Clinical Implementation and Transition. ARA and USAISR will identify the transition requirements and finalize the technology transition plan for the prototype CCS. (Task 3.5)
- Develop, complete final report.

3. Administrative

Applied Research Associates, Inc. (ARA) has been under Contract W81XWH-12-C-0126 to the U.S. Army Medical Research & Material Command's (USAMRMC) Telemedicine & Advanced Technology Research Center (TATRC) for two years. CCS prototype progress has been delayed due to unforeseen challenges in obtaining access to patient data and the databases required for Phase 2 development work. Based on this delay, we requested and obtained a no-cost extension to allow for the prototype to be developed and connected to a database with de-identified patient data. In October, the ARA team will apply for a No-Cost Extension (NCE) to accommodate a delay in the project schedule due to multiple causes, including IRB regulations and their interpretation, USAISR staffing, and delays in schedule as the team researched FIPS and DBIT compliance.

Meetings – The team participates in regularly scheduled team meetings and occasional WebEx conferences to further review and discuss the development of the CCS interface, the alignment of the clinical data requirements, and details for the integration of data from USAISR systems into the CCS system.

- CCS Phase 3 Weekly Tuesday check-in meetings
- CCS Phase 3 Weekly Thursday Technical Meetings and Demonstrations of the Prototype
- CCS Phase 3 Agile Development WebEx demonstrations, every other Thursday
- Experiment Design Meetings to develop Usability and Validation studies (May 2015; August 2015)

4. Equipment and Supplies

The team discontinued use of research funds for Schedule Anywhere on 5 May 2015, based on JPC-1 guidance. Prior to that date, ARA had purchased ScheduleAnywhere software from Atlas Business Solutions in the 11th Quarter of the project to address the need for the CCS to support clinician scheduling. ScheduleAnywhere directly satisfied requirements that Phase 1 research identified, and purchasing it was much less than the cost for the CCS development team to create it.

5. Reportable Outcomes

During the reporting period, the research team has produced the following professional publications, and presentations that are included in Appendices C, D, and J.

Journal

- Nemeth, C., Anders, S., Strouse, R., Grome, A., Crandall, B., Pamplin, J., Salinas, J., Mann-Salinas, E. *(in press*). Developing a Cognitive and Communications Tool for Burn ICU Clinicians. *Military Medicine*. Association of Military Surgeons of the United States (AMSUS).

Proceedings

- Nemeth, C., Pamplin, J.C., Grome, A., Laufersweiler, D, Blomberg, J., Hamilton, A., Salinas, J. *(In review).* Valid Point of Care IT for Improved Decision Making Precision. National Institutes of Health (NIH) IEEE Engineering in Medicine and Biological Science (EMBS) Strategic Conference. November 2015.
- Nemeth, C., Pamplin, J., Blomberg, J., Argenta, C., Serio-Melvin, M. & Salinas, J. Support for Salience: IT to assist burn ICU clinician decision making and communication. *Proceedings of the Systems Man and Cybernetics Society 2015 International Symposium.* Institute of Electrical and Electronic Engineers. Hong Kong. *(accepted)*
- Nemeth, C., Pamplin, J.C., Grome, A., Laufersweiler, D, Blomberg, J., Hamilton, A., Salinas, J. (2015, August). Building Cognition through Burn Intensive Care Unit Decision and Communications Support. Military Healthcare System Research Symposium. Ft. Lauderdale.
- Nemeth, C., Anders, S., Grome, A., Crandall, B., Dominguez, C., Pamplin, J., Mann-Salinas, E. & Serio-Melvin, M. (2014) Support for ICU resilience: Using Cognitive Systems Engineering to build adaptive capacity. *Proceedings of the Systems Man and Cybernetics Society 2014 International Symposium.* Institute of Electrical and Electronic Engineers. San Diego.
- Nemeth, C., Pamplin, J., Anders, S., Grome, A., Strouse, R., Crandall, C., Salinas, J. & Mann-Salinas, E. (2015, April). Developing a Cognitive and Communications Tool for Burn ICU Clinicians. Human Factors and Ergonomics in Healthcare Annual Conference. Human Factors and Ergonomics Society. Baltimore.
- Nemeth, C., Anders, S., Brown, J., Crandall, B., Grome, A., Mann-Salinas, E. & Pamplin, J. (2015, January). Developing a Cooperative Communication System for Safe, Effective, and Efficient Patient Care. *Society of Critical Care Medicine*. Phoenix.

Presentations

- Foundations of an ICU Decision Support and Collaboration System. 2015 International Conference of the Society for Critical Care Medicine. Phoenix.
- Invited presenter: The Human Factor in Engineered Systems. Faculty of Science and Technology, University of Macau. Macau, SAR, China. April, 2015.
- Invited presenter: Revealing Interdependencies: How Cognitive Systems Engineering Can Improve Resilience. The 2015 International Symposium on Computational Psychophysiology, Jinan, Shandong Province, People's Republic of China. April 3-6, 2015.
- Invited presenter: The Role of CSE in Individual and Team ICU Decision Making. DoD Human Factors and Engineering Technical Activities Group (HFE TAG). Orlando. 6 May 2015.
- Invited presenter: Realizing the Human Dimension Research Challenge Potential. Sandia National Laboratories. Albuquerque. 28 July 2015.

List of Appendices

- Appendix A. Revised Information Designs
- Appendix B. CCS Prototype, September 2014
- Appendix C. Presentation by Dr. Christopher Nemeth and LTC Jeremy Pamplin at the Military Health Systems Research Symposium (MHSRS), August 2014
- Appendix D. Support for ICU Clinician Cognitive Work through CSE (author proof)
- Appendix E. CCS USAISR 5-9 January 2015 Visit Interface Review Notes Data Review
- Appendix F. Trip report: USAISR User Interface Data Collection 04-09 January 2015
- Appendix G. Evaluation Protocol CCS User Interface Prototype (In-progress)
- Appendix H. CCS Requirements Validation Survey Memo
- Appendix H1. Open Narrative Responses Organized by Topic
- Appendix I. Data Requirements
- Appendix J. Society of Critical Care Medicine (SCCM) Poster
- Appendix K. SSCI Activity Summary
- Appendix L. CCS Glossary (Draft)
- Appendix M. Trip report: ARA SED Machine Learning team trip to USAISR 13-17 April 2015.
- Appendix N. Nemeth, C. Revealing Interdependencies: *How Cognitive Systems Engineering Can Improve Resilience*. The 2015 International Symposium on Computational Psychophysiology, Jinan, Shandong Province, People's Republic of China. April 3-6, 2015.
- Appendix O. Nemeth, C. Invited presenter: *The Human Factor in Engineered Systems*. Faculty of Science and Technology, University of Macau. Macau, SAR, China. April, 2015.
- Appendix P. Updated CCS Prototype – Configurable Patient View
- Appendix Q. Poster Presented by Dr. Chris Nemeth at the Human Factors and Ergonomics Society (HFES) Healthcare Symposium, Baltimore, Maryland. April 2015.
- Appendix R. Presentation by Dr. Christopher Nemeth at the Department of Defense Human Factors Engineering Technical Advisory Group Meeting: *The Role of CSE in Individual and Team ICU Decision Making.* 6 May 2015.
- Appendix S. Nemeth, C., Anders, S., Strouse, R., Grome, A., Crandall, B., Pamplin, J., Salinas, J., Mann-Salinas, E. *(in press*). Developing a Cognitive and Communications Tool for Burn ICU Clinicians. *Military Medicine*. Association of Military Surgeons of the United States (AMSUS).
- Appendix T. Nemeth, C. Invited presenter: *Realizing the Human Dimension Research Challenge Potential*. Sandia National Laboratories. Albuquerque, New Mexico. 28 July 2015.
- Appendix U. Poster Presented by Dr. Christopher Nemeth at the Military Health System Research Symposium (MHSRS). Fort Lauderdale, Florida. August 2015.
- Appendix V. Nemeth, C., Pamplin, J.C., Grome, A., Laufersweiler, D, Blomberg, J., Hamilton, A., Salinas, J. *(In review). Valid Point of Care IT for Improved Decision Making Precision*. National Institutes of Health (NIH) IEEE Engineering in Medicine and Biological Science (EMBS) Strategic Conference. November 2015.
- Appendix W. Nemeth, C., Anders, S., Grome, A., Crandall, B., Dominguez, C., Pamplin, J., Mann-Salinas, E. & Serio-Melvin, M. (2014) Support for ICU resilience: Using Cognitive Systems Engineering to build adaptive capacity. *Proceedings of the Systems Man and Cybernetics Society 2014 International Symposium.* Institute of Electrical and Electronic Engineers. San Diego, California. October 2014.
- Appendix X. Nemeth, C., Pamplin, J., Blomberg, J., Argenta, C., Serio-Melvin, M. & Salinas, J. *(accepted).* Support for Salience: IT to assist burn ICU clinician decision making and communication. *Proceedings of the Systems Man and Cybernetics Society 2015 International Symposium.* Institute of Electrical and Electronic Engineers. Hong Kong, People's Republic of China.

6. Conclusions

During Phase 2, the ARA team completed requirements, user-oriented use cases, and information design prototypes based on Phase 1 findings. The team developed multiple versions of a CCS software prototype, translating the information design's organization and information into an interactive interface. We replaced an under-performing subcontractor with an exceptional ARA machine learning team that has successfully scaled learning algorithms and integrated them into the interface.

The main challenge during this period has been compliance with, and appropriate reinterpretation of, regulations that has caused noticeable delays. While we have successfully dealt with these issues, we will apply for a no-cost extension to mitigate the delay's effects.

As the project continues its final phase, we will:

- Finish mapping data from the Essentris database,
- Complete plans for and conduct usability and validation assessments at the BICU
- Analyze data from both individual and team assessments
- Develop and complete a final report including transition recommendations

The system the process produces is expected to improve communication, information flow, and workflow among and across clinical providers and support staff.

7. References

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8. Appendices

Appendix A. Revised Information Designs

Appendix A contains illustrations of the most recent CCS user interface information design prototypes . They include: Patient identifier, Patient Systems view, Rounds "child-parent detail" – Rehabilitation, Unit view, and Family Member view.

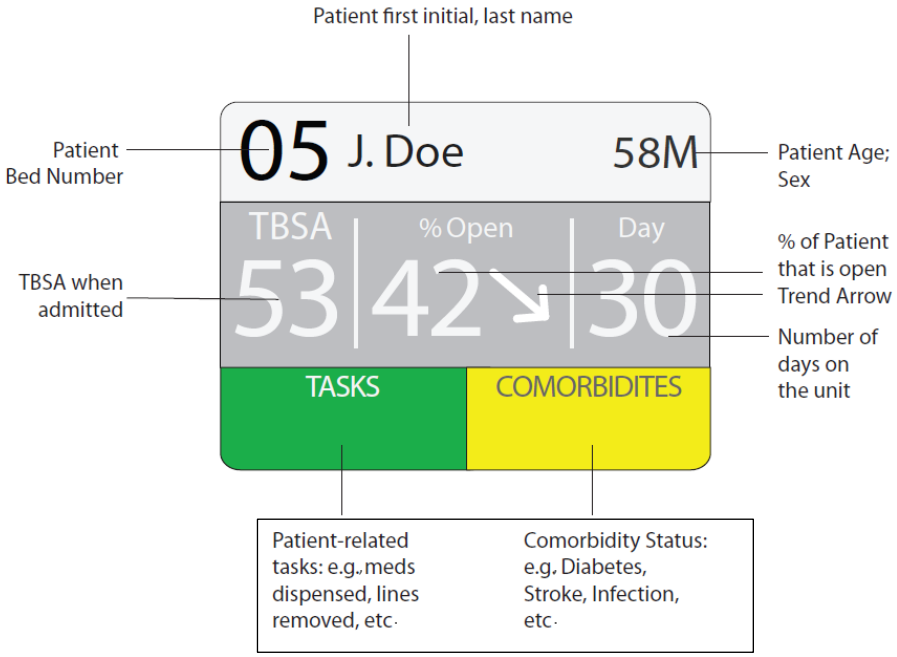

Figure A-1. Patient Identifier "widget"

Figure A-1 illustrates the Patient Identifier "widget" that will be unique to each BICU patient. This hypothetical example represents a Patient "J. Doe" in Room 5, a 58-year old male with a 53% TBSA when admitted. The patient has been on the BICU for 30 days and, while 42% skin surface area is still open, the down arrow indicates the rate of healing is declining. While required tasks are current (shown in green), data appear to indicate (shown in yellow) that other aspects of his condition (such as infection) are in decline and merit attention.

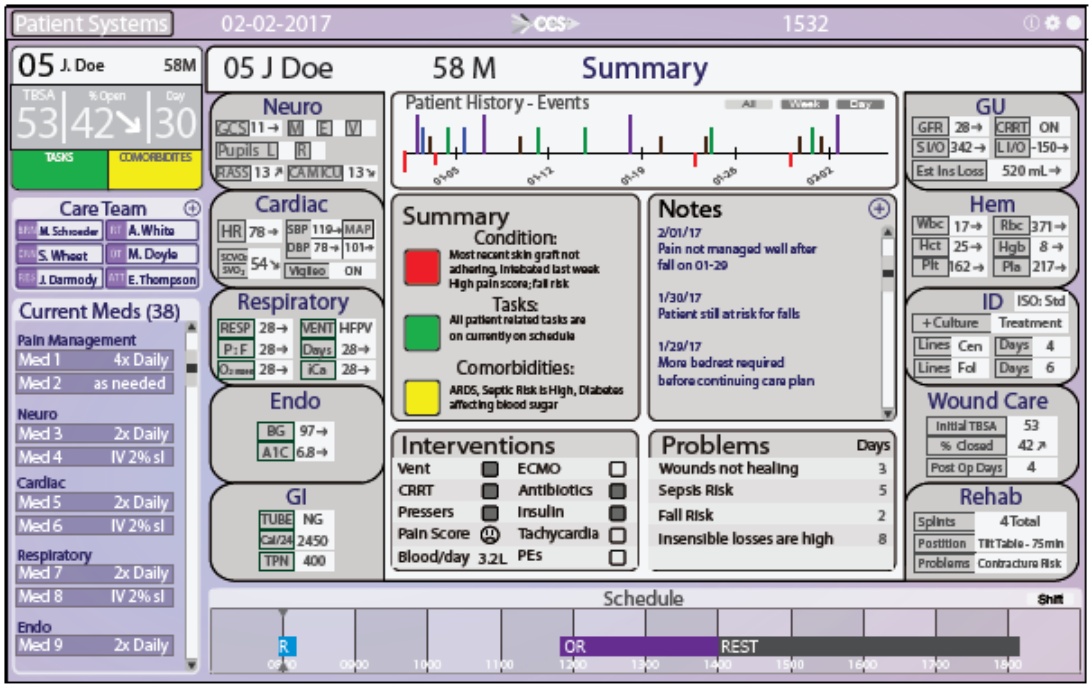

Figure A-2. Patient Systems view. Includes Patient Identifier, summaries of key patient data sorted by system, the patient's care team members, current medications by system, and status.

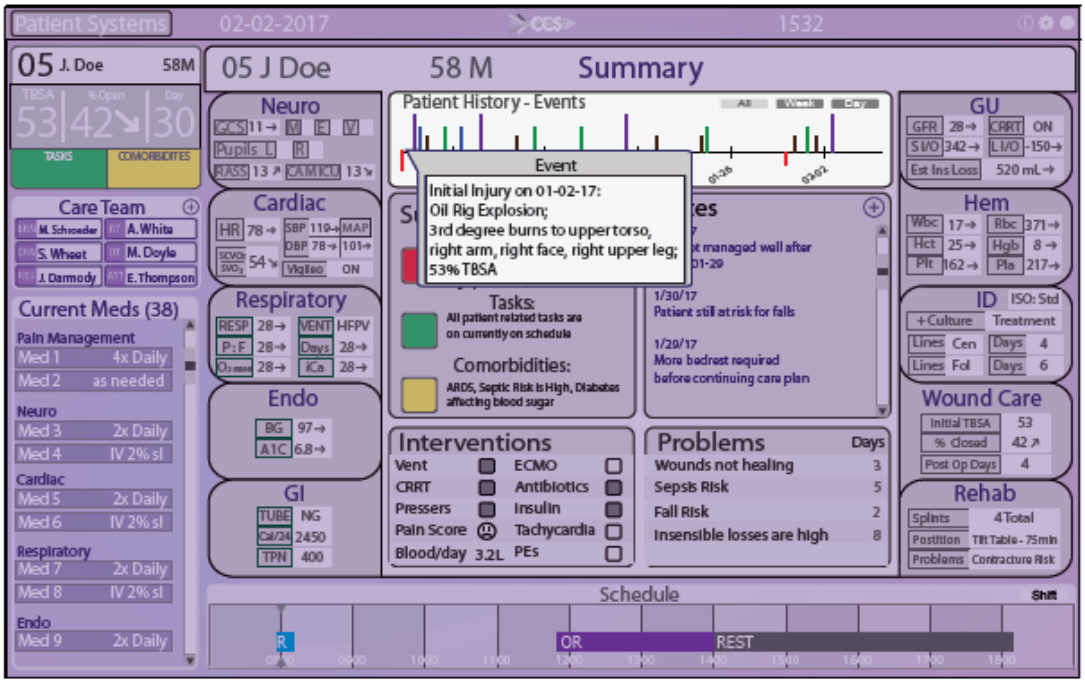

Figure A-3. Patient Systems view, showing how suggested pop-up window would provide explanation of events on the patient history timeline. In this instance, the window describes the event causing injury (an oil rig explosion) and diagnosis upon admission

Figures A-4 through A-12 demonstrate views according to Patient Systems, using the "parent-child" screen management technique described earlier in this report.

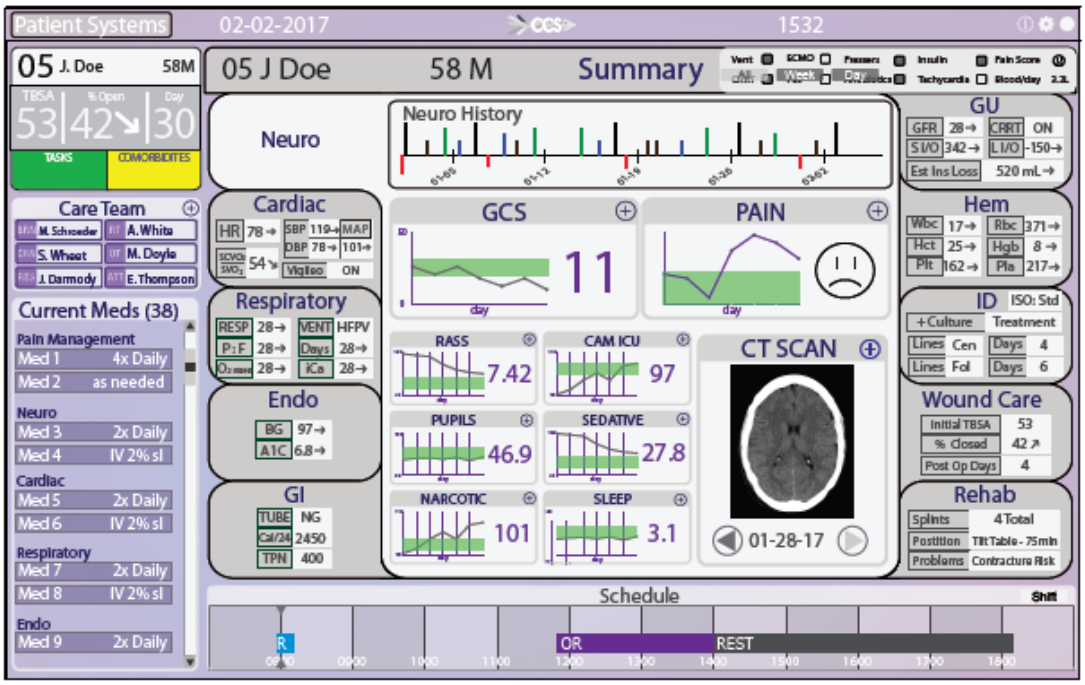

Figure A-4. Patient Systems view – Neurology (Neuro).

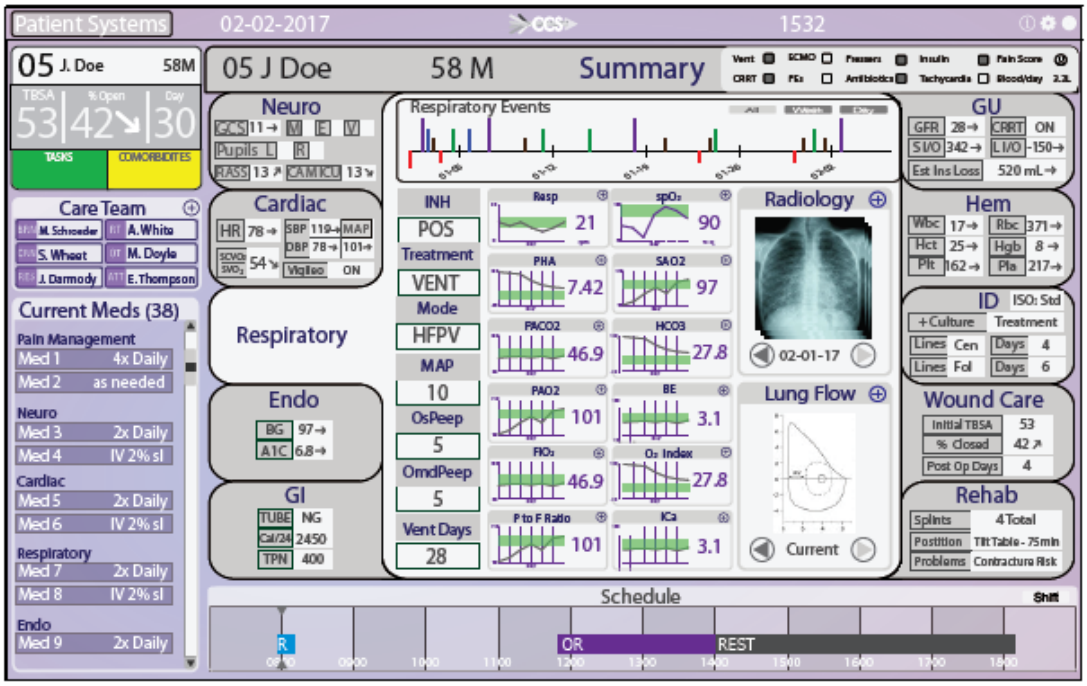

Figure A-5. Patient Systems view – Respiratory.

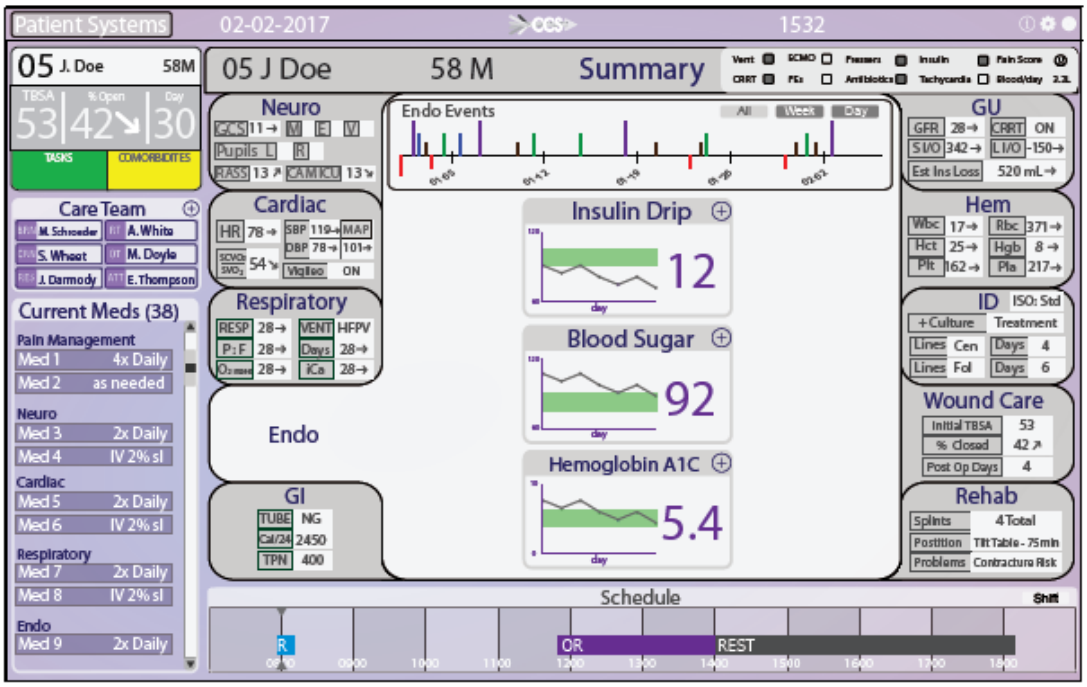

Figure A-6. Patient Systems view – Endocrine (Endo).

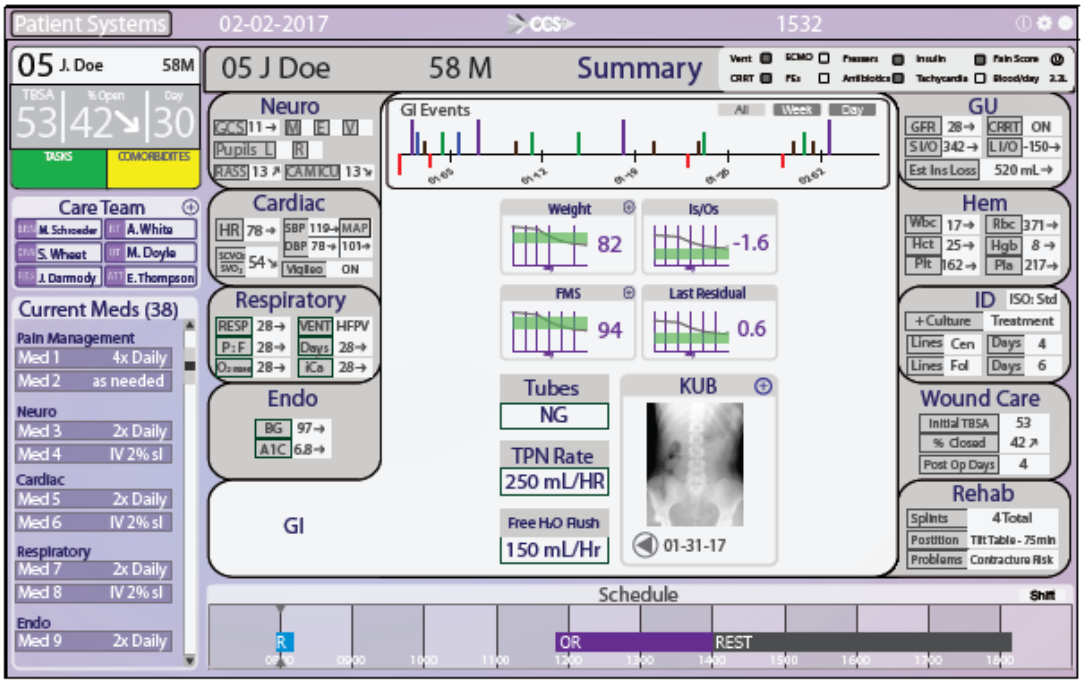

Figure A-7. Patient Systems view – Gastrointestinal (GI).

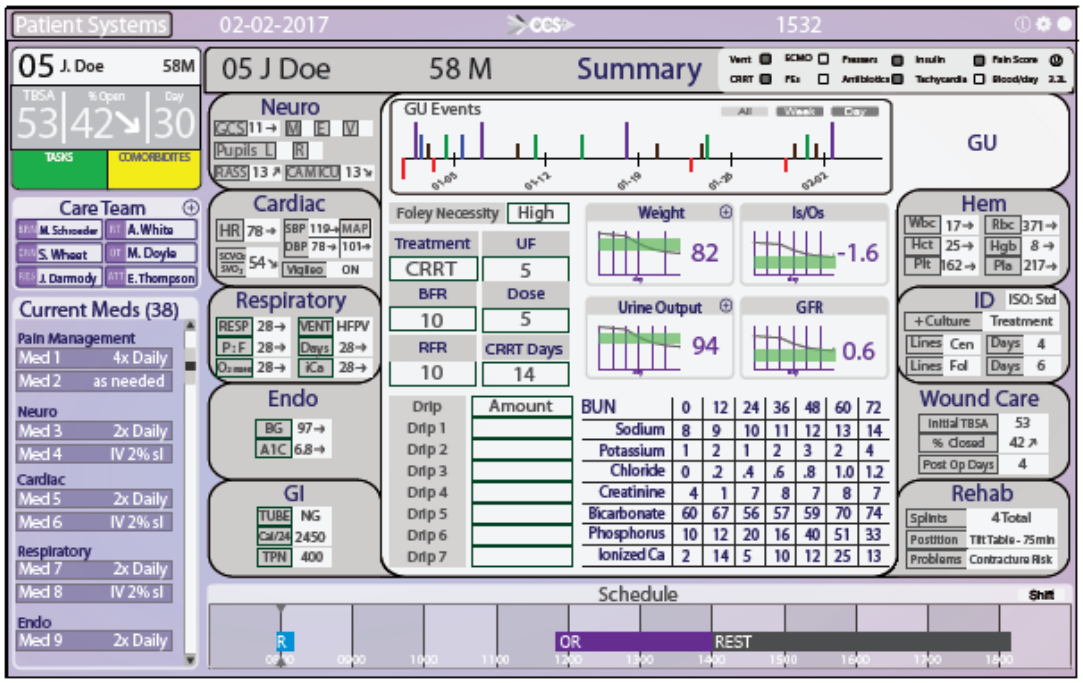

Figure A-8. Patient Systems view – Genitourinary (GU).

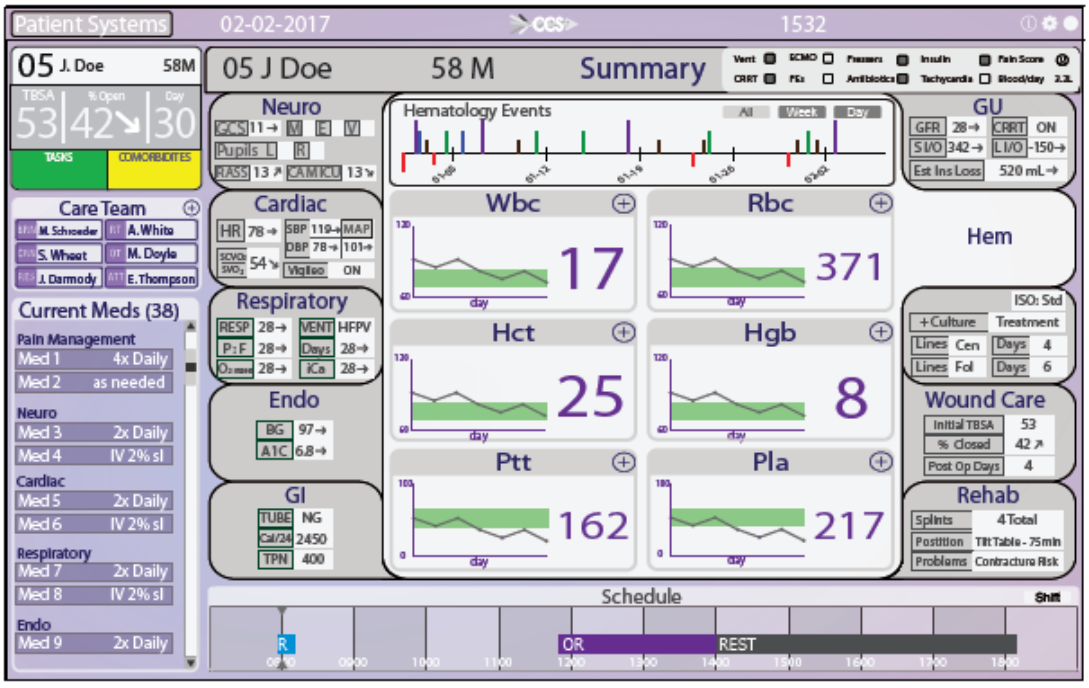

Figure A-9. Patient Systems view – Hematology (Hem).

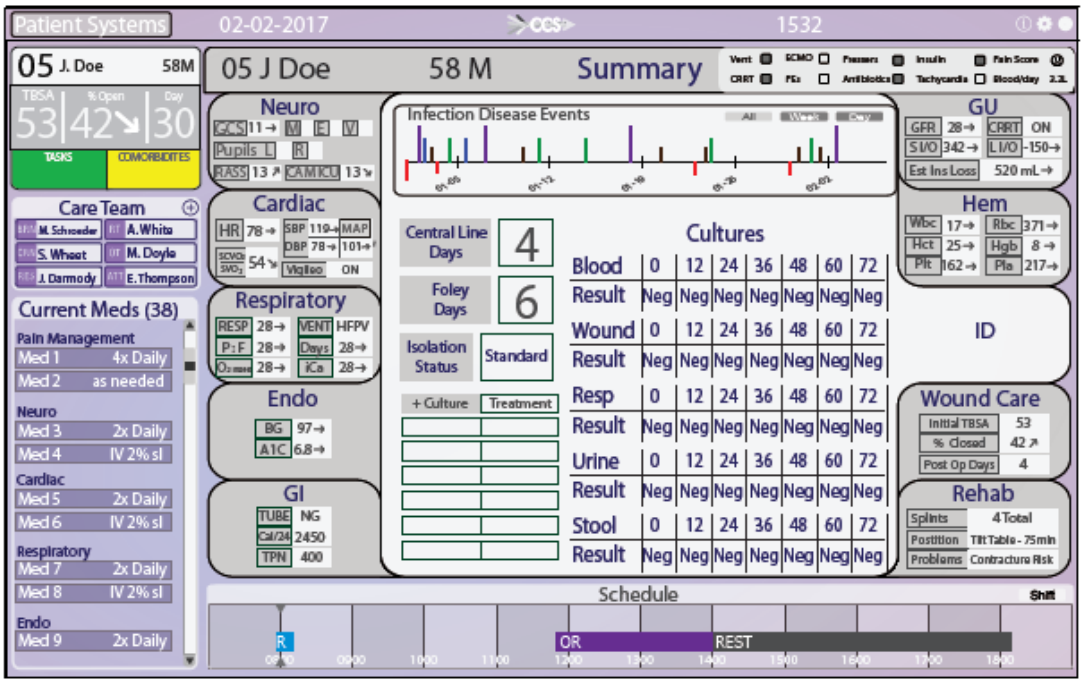

Figure A-10. Patient Systems view – Infectious Disease (ID).

Figure A-11. Patient Systems view – Wound Care.

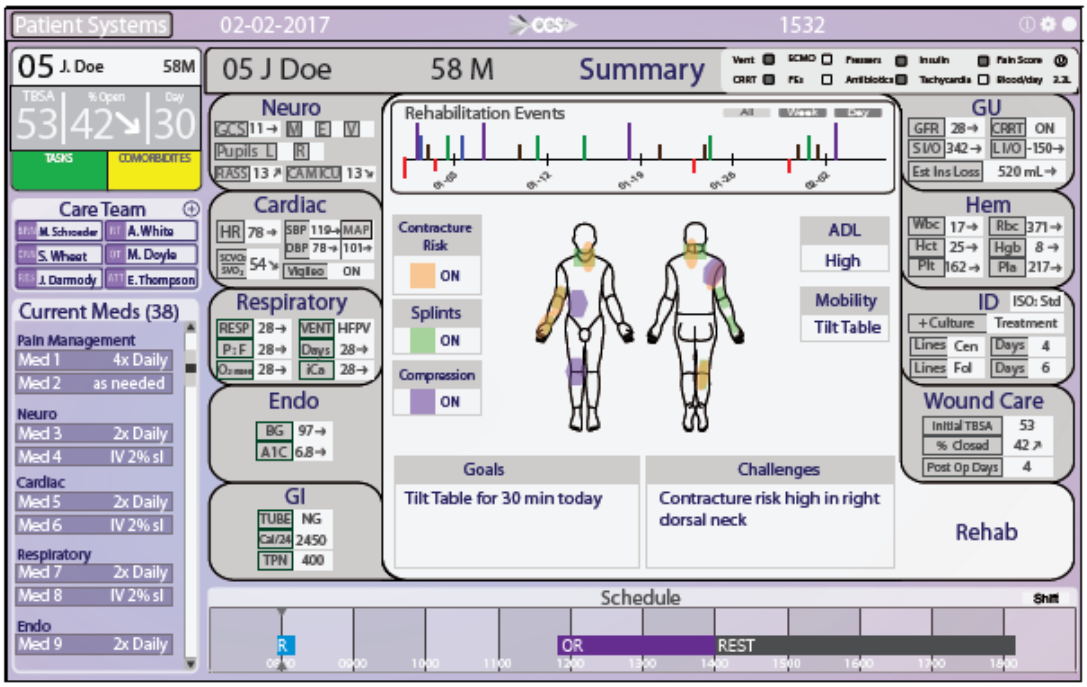

Figure A-12. Patient Systems view – Rehabilitation (Rehab).

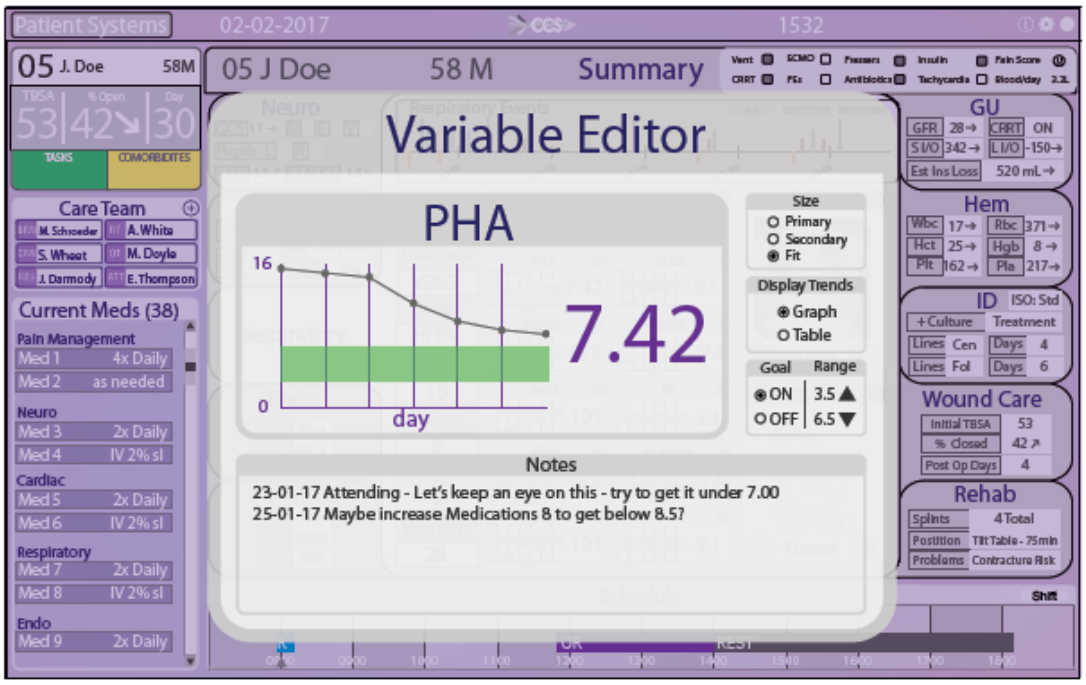

Figure A-13. Patient Systems view – Demonstrates how a clinician might edit parameters for particular variables, such as minimum and maximum acceptable values.

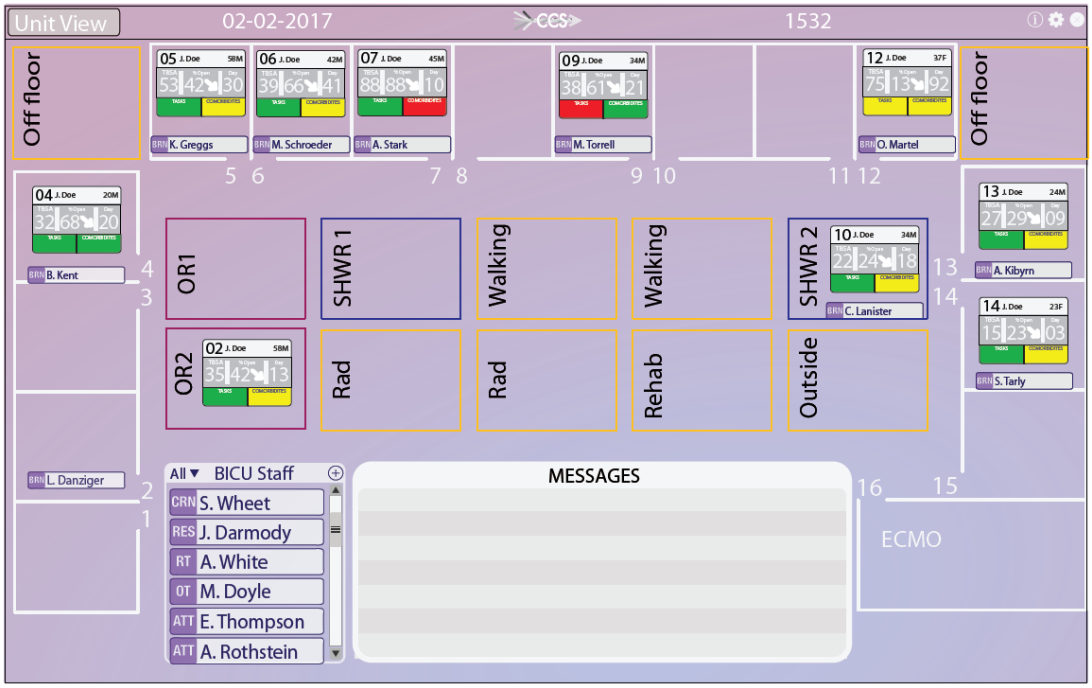

Figure A-14. Unit view.

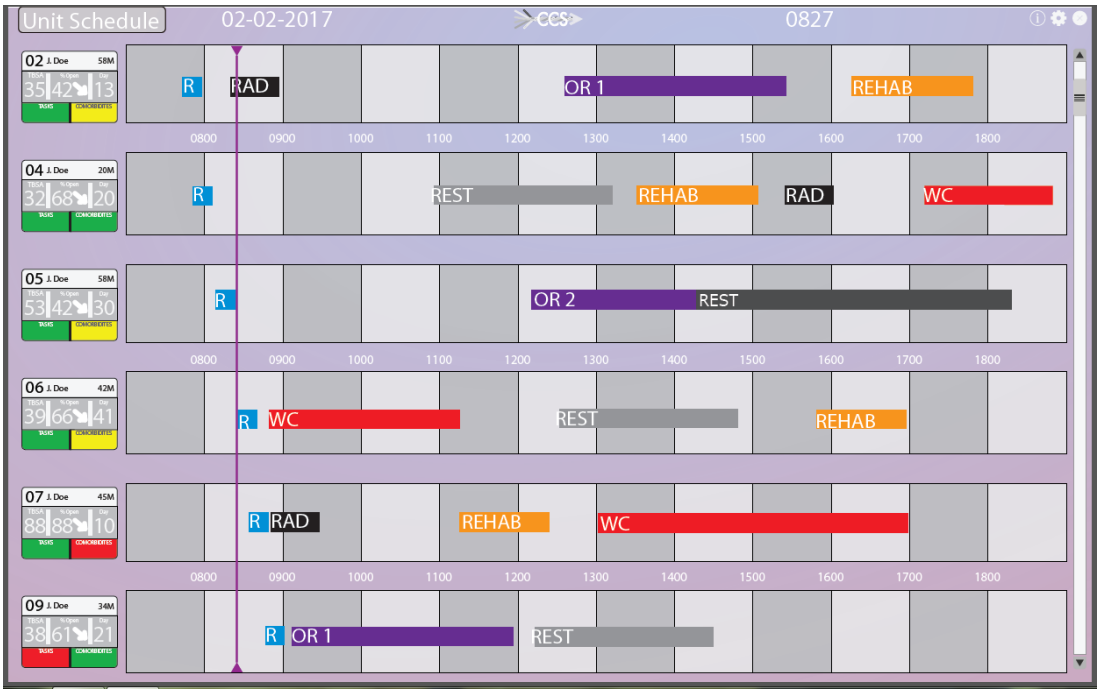

Figure A-15. Unit schedule.

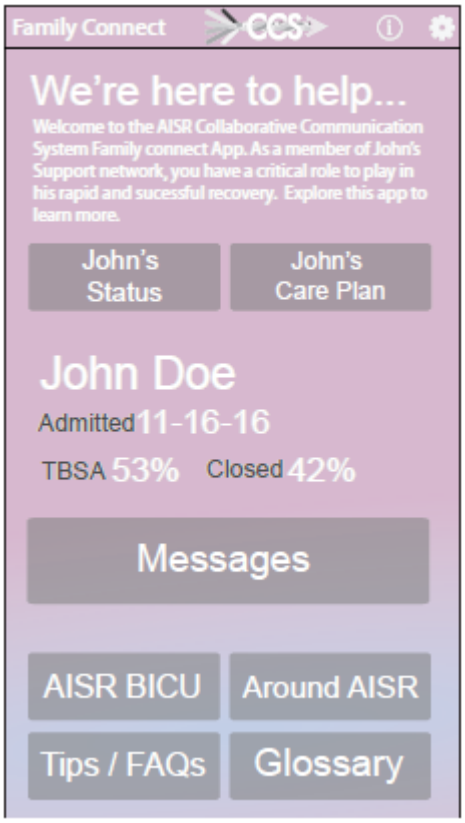

Figure A-16. Family view.

Appendix B. CCS Software Prototype, September 2014

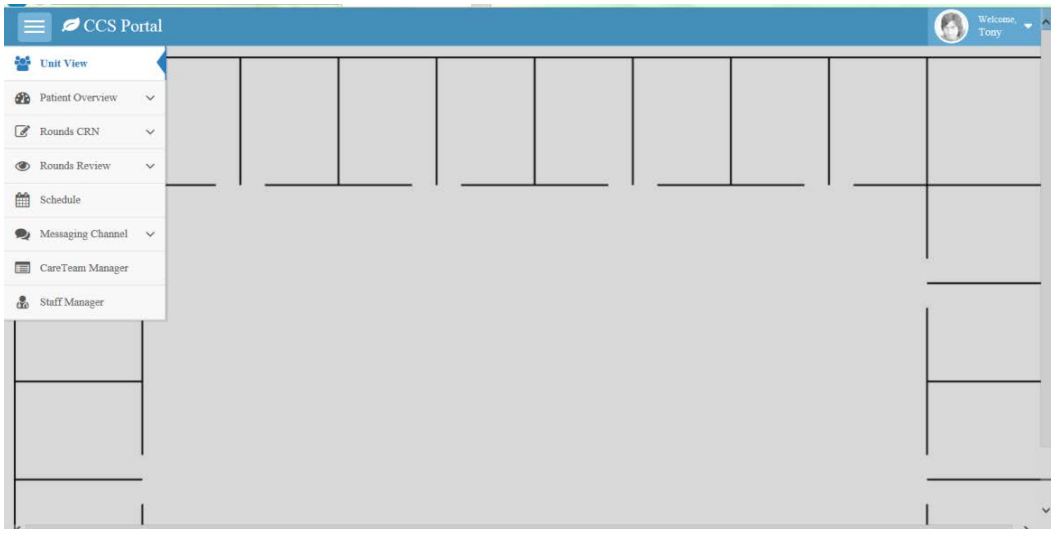

Figure B-1. Unit view and menu options.

Figure B-2. Patient view and cardiac details.

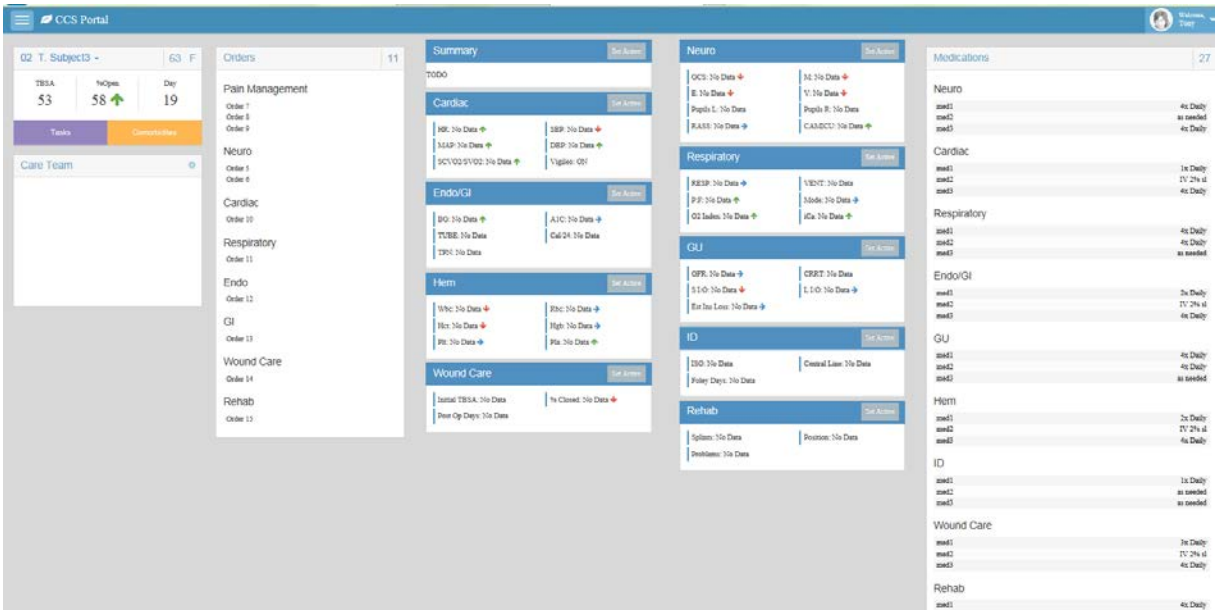

Figure B-3. Rounds review.

Figure B-4. Messaging channel.

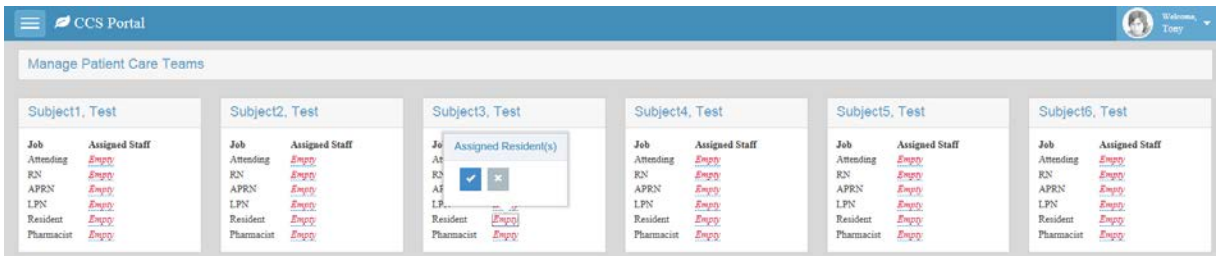

Figure B-5. Care team manager.

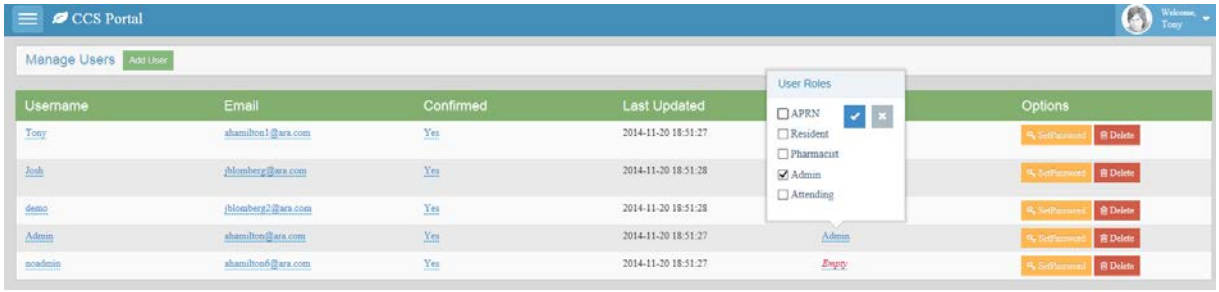

Figure B-6. Staff manager.

Appendix C. Presentation by Dr. Christopher Nemeth and LTC Jeremy Pamplin at the Military Health Systems Research Symposium (MHSRS), August 2014

expanding the realm of POSSIBILITY®

Developing a Cognitive and Communications Tool for Burn ICU Clinicians

US Army Medical Research and Materiel Command
Contract No.W81XWH-12-C-0126.

Presented by

Christopher Nemeth, PhD, CAPT USNR (Ret.), Applied Research Associates

LTC Jeremy Pamplin, MC, Army Institute for Surgical Research

To

Military Healthcare Research Symposium

Date

18 August 2014

ARA

expanding the realm of POSSIBILITY®

Research Topic Area: Bio-Informatics (1)

Supporting Warrior Care

Findings from projects/studies aimed at promoting, improving, conserving or restoring personnel mental or physical well-being through improved information management & use of emerging technologies

Photo: Dept. of the Army

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2

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Objectives for This Session

- Become familiar with the nature of and need for human subject field research in military healthcare work settings
- Become familiar with the use of human factors methods such as Cognitive Systems Engineering to understand and support military healthcare
- Understand how human factors can help to improve military healthcare reliability, safety, efficiency, and resilience.

Photo: Dept. of the Army

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3

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Research Site

- Burn ICU in tertiary care medical center,
- 16 beds, 2 reserved to serve as a post-anesthesia care unit (PACU), 1 dedicated to support Extracorporeal Membrane Oxygenation (ECMO).
- Other nearby units support the ICU, including a step down unit, burn operating room, and outpatient clinic.
- Population averages around 8 patients but as high as 13
- Patients have severe affliction from chemical, mechanical or electrical burns, or burn-like afflictions such as toxic epidermal necrolysis (TENS).
- Length of stay ranges from days to months.

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4

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Research Design

- Goal is to improve care by better supporting the judgment of individuals and teams who care for patients through a cognitive aid that also assists communication.
- Three phases that are scheduled to take roughly a year apiece: foundation research, cognitive aid prototype development, and prototype assessment.

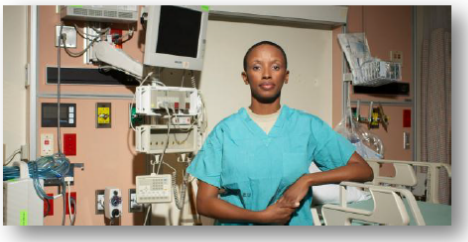

Photo: Dept. of the Army

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5

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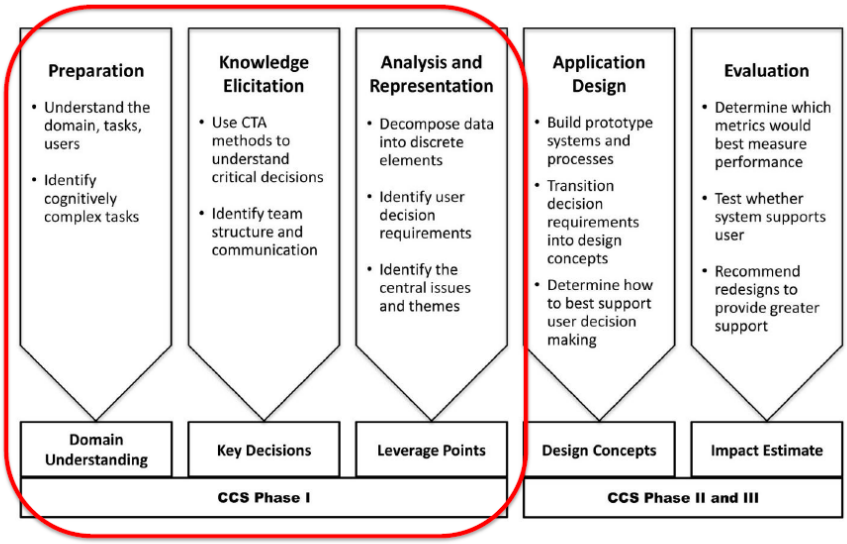
Cognitive Systems Engineering Phase 1



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6

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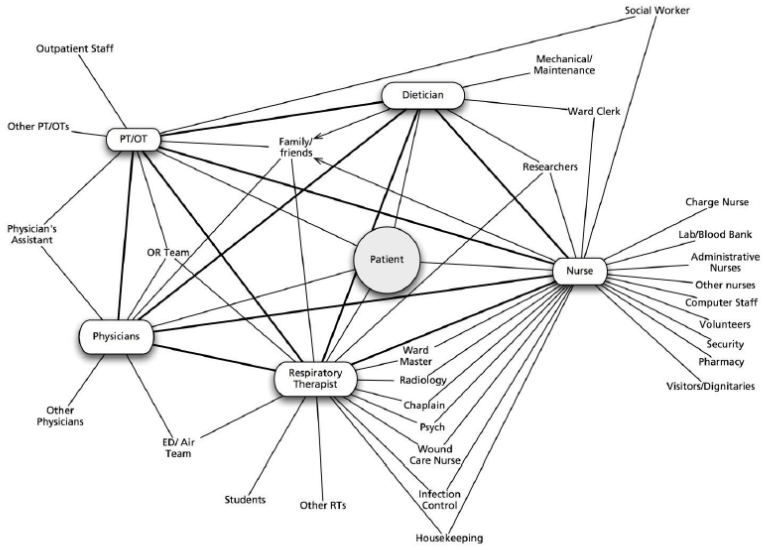
BICU Patient Team



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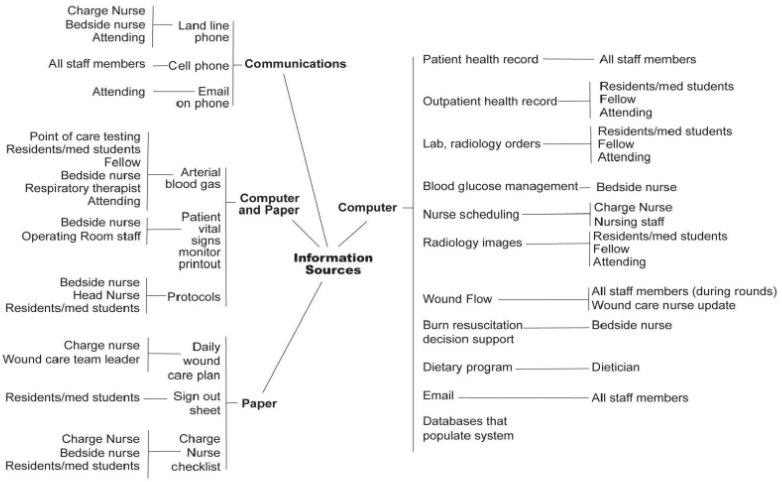
BICU Information Sources



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BICU Cognitive Model

Function Unit Members Perform	*Activities Unit Members Perform*	*Tasks Unit Members Perform*
Synchronization	Clarification	Reduce uncertainty Manage ambiguity Manage conflicting agendas Manage communication
	Coordination	Develop shared awareness of the Patient Get and keep common ground Manage the care plan and treatment goals Coordinate resources
	Negotiation	Identify alignment, gaps/differences (e.g., agendas) Manage conflicting agendas Manage communication
	Anticipation	Forward thinking

ARA

9

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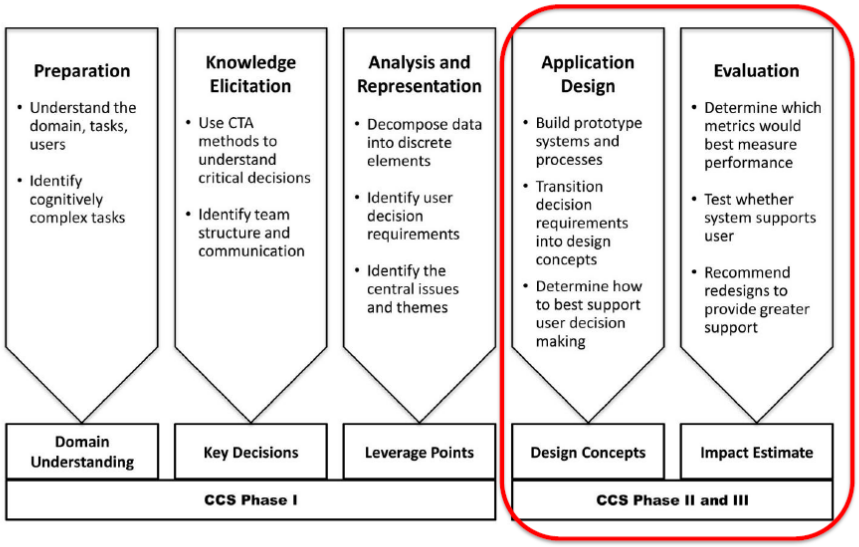
Cognitive Systems Engineering Phases Two, Three



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10

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Patient View

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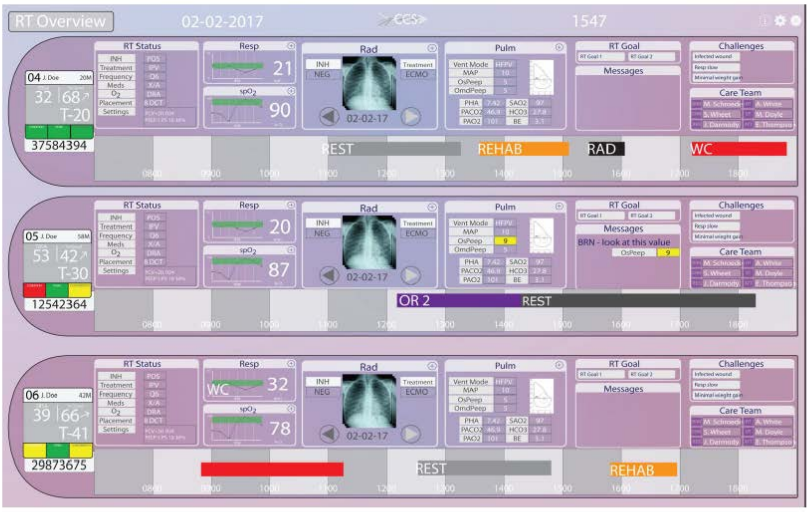
Clinician-Specific View: RT



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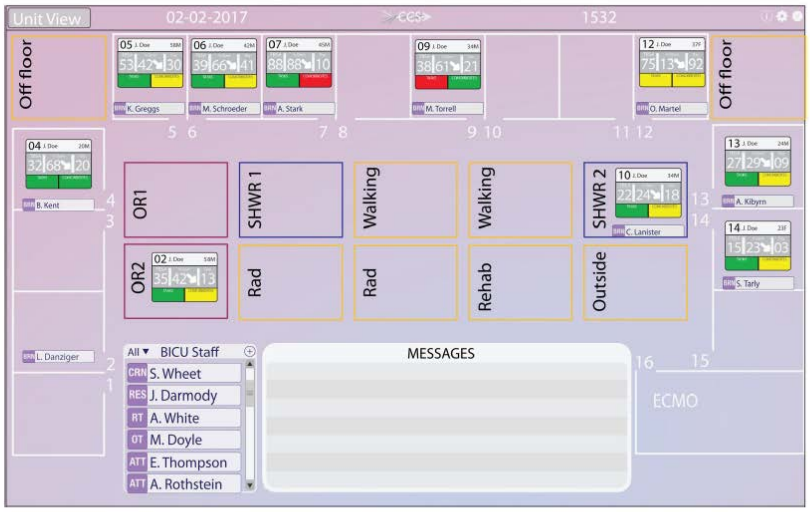
Unit View



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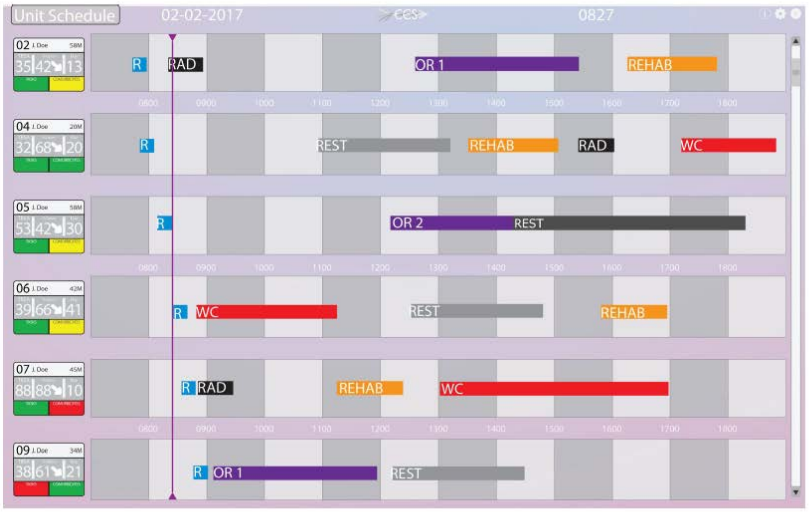
Unit View: Schedule



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Pop Quiz!

Q. What's the hardest part of this project so far?

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Pop Quiz!

Q. What's the hardest part of this project so far?
A. Access to patient data.

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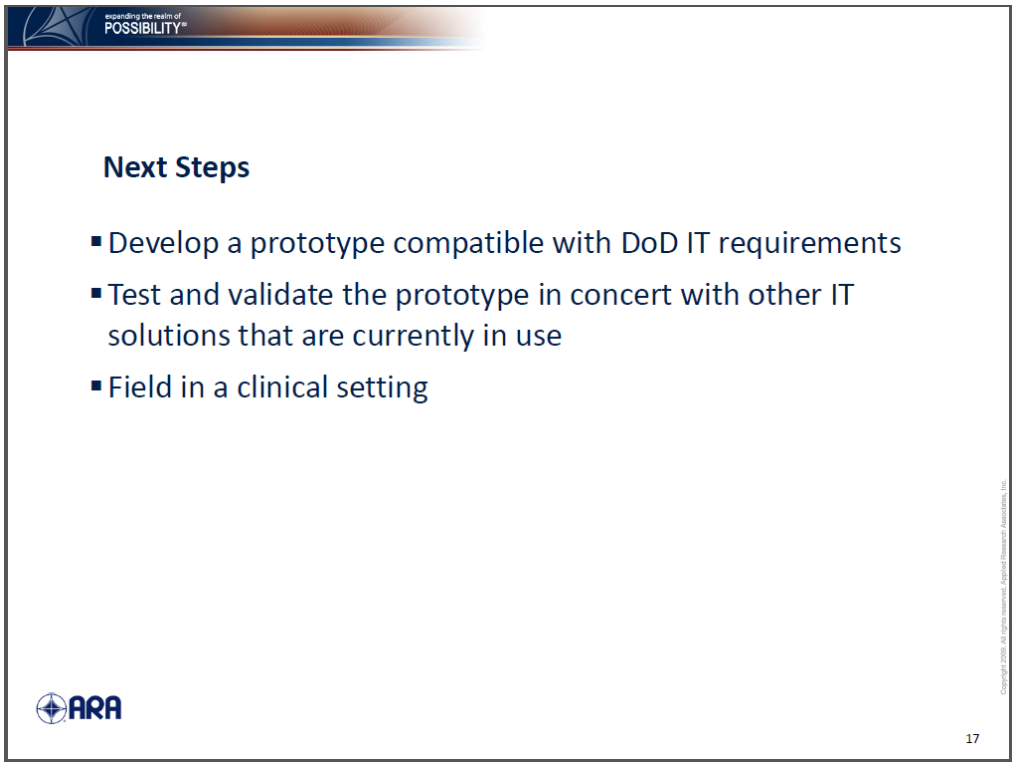
16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POSSIBILITY℠
Next Steps
Develop a prototype compatible with DoD IT requirements
Test and validate the prototype in concert with other IT solutions that are currently in use
Field in a clinical setting
ARA
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Appendix D. Support for ICU Clinician Cognitive Work through CSE (author proof)

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Support for ICU Clinician Cognitive Work through CSE

Christopher Nemeth, Shilo Anders, Jeffrey Brown, Anna Grome, Beth Crandall, and Jeremy Pamplin

CONTENTS

Introduction

"...operators pursue goals in complex work domains..." - edits OK?

Cognitive systems engineering (CSE) has been proven to be useful in revealing key aspects of operator behavior as operators pursue goals in complex work domains, providing the foundation for the development of solutions that are ecologically valid. Health care work settings, particularly the intensive care unit, present one of the most challenging work domains for a researcher to study. Cognitive engineering methods (Hollnagel and Woods 1983; Woods and Roth 1988; Roth et al. 2002; Militello et al. 2010) can be applied to understand characteristics of complex work domains such as the ICU as well as the behavior of workers including clinicians and their support staff. The use of CSE methods makes it possible to identify key traits of health care work settings, such as decisions clinicians make, obstacles clinicians face, and initiatives they take to overcome these obstacles in their efforts to restore patients to the best possible health. CSE methods also have the potential to enable workers to better understand their unit's performance and more successfully adapt to unforeseen challenges—in other words, to be *resilient*.

This chapter describes a project using CSE methods that is underway at a burn intensive care unit (BICU) in a major military medical center. This project will develop an ecologically valid computer-based cognitive artifact (Hutchins 2002) that will support individual and clinical team decisions and communication.

Background

The study of health care relies on the use of proven methods by qualified researchers. This is because work at the sharp (operator) end of health care is (among other traits) dense, time-pressured, and complex. Expert workers can find it difficult to be objective observers of their own activities and work settings. Because of this, studying one's own system may yield conclusions that are logical but may also miss deeper issues. Attention in such studies often focuses on a single theme while excluding the many elements that interact with each other to produce a collective result—its context.

For example, *closed claims reviews* that conclude that error elimination will remove "error causes" ignore the complex pressured context that molded each event. It assumes that a claim will contain all of the information that needs to be known about an adverse outcome. It also presumes to know what caused that outcome, that it was caused by an "error," and that its cause can be "eliminated."

Retrospective records review relies on historical documentation in order to draw conclusions about care and its related risks. But records hold little of the context, speculation, deliberation, and complex trade-off decisions that typically mold any significant event.

Voluntary reporting systems have been touted as tools to incorporate error reporting and analysis into the culture of medicine (Plews-Organ et al. 2004). However, voluntary reporting fails to note how the approach is vulnerable to social and organizational influences.

Clinical discussions of patient safety often review how effective a single diagnostic or therapeutic intervention is without taking other factors into account that would affect outcomes in actual practice. For example, Shojania et al. (2001) tested the use of a single item to prevent infections: a maximum sterile barrier when placing intravenous catheters. Some clinicians attempt to make system analysis easier by bounding the problem through selection and management of a single variable. Kyriacou et al. (1999), for example, sought to measure and reduce the length of stay in the emergency department. Some clinicians have applied methods such as workload assessment to the ED, but they found that the level of effort that is required makes it difficult to routinely use it as a measurement tool (Levin et al. 2006). Others have imported measures from other sectors to measure a single aspect of ED operation. For example, France and Levin (2006) used the notion of "system complexity" to determine safe capacity during care demand surges but conceded that phenomena such as interruptions need to be added.

Research that does not adequately detect or understand these issues diverts valuable resources into low-yield efforts. Research that reveals context will grasp the constraints that shape opportunities and risks in practice, curb the influence of hindsight and outcome bias, and yield valid solutions that gain traction in actual work settings (Wears and Nemeth 2007). A current intensive care unit study provides an illustration of how the use of CSE makes that possible.

Research Design and Methods

Our research team is completing the first part of a three-year study to develop a computer-based cognitive aid that supports cognitive work and communication. While it is still in its early stages, it can serve as an example

of CSE's value in health care. We discuss the CSE approach in this chapter in the context of our work on a prior project that described quality standards for how to conduct CSE research.

Quality

Nemeth et al. (2011) described the use of CSE in a Navy-funded project that demonstrated how to use the CSE approach in the context of the Department of Defense acquisition process. The project's results would be used by government staff members and contractors who have no prior CSE training or experience. The approach needs to be used well to produce useful results. How would the new users know what that is? The team conceived of "reasonable scientific criteria" as a way to guide new users through CSE in a manner that is scientifically rigorous and that links design recommendations directly to operator needs. Using steps in the CSE process, the team considered the goals and activities at each stage, case studies from the literature that exemplified each stage, and ways that performance and scientific rigor could be evaluated at each stage. In order to do that, the team considered three questions:

- What reliability/validity criteria are important and reasonable to apply to CTA data?
- What are the standards of practice, and what needs to be done to meet those standards?
- How can a rigorous process be created and followed while also being open to discovery with respect to process and outcome?

Answers to these questions identified a set of quality standards for each stage of the CSE process (Table 7.1) from Nemeth et al. (2011) that can also be applied to research in the health care context.

In the section Research Process, we describe how the first three standards have guided our efforts during the project's first year. The standards for "Application: design" and "Evaluation" will guide our work in the project's second and third years.

Research Design

Our project's goal is to improve patient care by better support of the judgment of BICU clinicians and teams by developing a cognitive aid that assists in decision making and communication. The project's three phases are scheduled to take roughly a year apiece for foundation research, cognitive aid prototype development, and prototype assessment. The first-year goal was to develop a thorough description of individual and team cognition that will provide the basis for cognitive aid prototype development in the second year as well as criteria for prototype assessment in the third year.

TABLE 7.1

Reasonable Scientific Criteria for CSE

CSE Step	Standards
1. Preparation and framing	Clear statements of • Issue or problem • Framing activities outcome • Method, settings, project participant selection rationale
2. Knowledge elicitation	Use of multiple knowledge elicitation (KE) methods Use of interview and observation guides Purposeful sampling of participants and settings Qualified prepared data collectors Quality control protocols (specified format to document data) Manage the dual requirements for rigor and flexibility
3. Analysis and representation	Systematic, purposeful, and documented analysis process Audit trail to connect data elements to findings to design elements Multiple analysis processes and multiple passes thru the data Qualified analysis team members Validity checks on findings Goal-driven selection of qualitative versus quantitative analysis Use of reliability indices
4. Application: design	Iterative design–build–evaluate process Subject matter experts (SMEs) for credibility checks Audit trail to connect data elements, to findings, to design
5. Evaluation	Clear assessment criteria Review evaluation results systematically and purposefully Evaluation methods reflect key cognitive components, behaviors Outcomes reflect cognitive and behavioral issues critical for cognitive work Verify whether the design/changes improve performance

"The five member core team members" was changed to "The five core team members". Please check if OK.

The five core team members are experienced in health care field studies using CSE methods and are located remotely from the research site. To manage this, they retained a licensed vocational nurse (LVN) at the site to help with the administrative aspects of research team visits. All data collection and human subject consent were carried out under the jurisdiction of the medical center's Institutional Review Board (IRB), which reviewed and approved the research protocol. In advance of the team's first trip to the site, the Co-PI and LVN obtained the consent of health care team members working in the BICU who were willing to participate in the study. Those who declined to participate were excluded from observations and interviews.

Research Site

The research site is a BICU located in a new wing of a federally funded 450-bed tertiary care military academic medical center. The 16-bed unit is widely considered to be one of the best of its kind in the country. Two of the ICU beds are reserved to serve as a postanesthesia care unit (PACU), and another is dedicated to support the center's extracorporeal membrane

oxygenation (ECMO) program. Other nearby units support the ICU, including a step-down unit, dedicated burn operating room, and an outpatient clinic. The typical census averages around 8 patients but has risen to as high as 13 during our study period. This unit's role as a regional tertiary care unit attracts patients who have the most severe affliction from thermal, chemical, mechanical, or electrical burns. It treats patients with burn-like diseases of the skin such as toxic epidermal necrolysis, Stevens–Johnson syndrome, and the autoimmune disorder pemphigus vulgaris. The unit also treats patients with infections or trauma that causes extensive soft tissue damage or loss, such as necrotizing fasciitis, severe degloving injuries, and some war-related trauma. Patient length of stay ranges from days to more than 12 months.

Sample

All clinicians, patients, and patients' friends and family members are potential participants in the study. By the end of the study, we anticipate that over 150 clinicians will be included in the sample. Subjects are recruited through word of mouth in coordination with the BICU medical director and head nurse. Patients in the BICU (or their legal representative) are asked at the start of an observation period to complete a Health Insurance Portability and Accountability Act release before observation or interview. No clinical information collection or recordings are made in the presence of any patient who declines to complete the release. Patient medical data that are necessary to clinical decision making are collected without protected health information and are used only as examples of information that clinicians need to do their work.

Methods

The study of human behavior requires repeated samples to capture its richness, complexity, and variation. No method by itself can account for this complexity. As a result, multiple methods need to be used in order to ensure that the account is valid and as accurate as possible. The research design for this project relies on multiple methods to triangulate data collection and analysis: observation, interviews, and artifact analysis. Comparison of data among all of these sources minimizes the potential bias that a single method may induce.

Observation

In-person observation makes it possible for the research team to witness the phenomena of patient care and team collaboration *in situ*. Informal probe questions enable the researchers to request background and clarifying information in the context of the situation. Observations can be used to study the ways that practitioners perform diagnoses and prepare, launch, monitor,

adjust, and complete patient care. The research team performs observations at various times throughout the day and evening to include a range of circumstances and clinicians' responses. Conditions can range from quiet routine to rapid changes. These can happen during the admission or discharge of multiple patients, emergent conditions such as treating rare emergencies like cardiac arrest or burn shock, and common emergencies such as treating postoperative hemodynamic instability.

Observation also includes informal interviews with clinicians as they work in order to learn the bases for their decisions or apparent indecision, motivations, expectations, and preferences that observation alone cannot reveal. Field notes that researchers make during observation provide data for analysis to reveal patterns among and across clinicians. Observations make it possible to describe the ways that individuals and groups cope with complexity and uncertainty. Research team members pay particular attention to heuristics (rules of thumb), and clinicians have developed their expertise and knowledge about individual and system performance, how they use systems such as the electronic health record, mental simulations they perform, and how they assess outcomes. The research team also watches for how the unit members resolve discrepancies and conflicts, negotiate trade-off, evaluate the credibility of data and information from others outside of the unit, and mentor and coach junior members.

During the first visit, team members visited the unit for five weekdays during the day shift (0800–1600). The team scheduled regular observations on the ICU to avoid interfering with clinical work. Subsequent visits to the site also covered evening and night shifts.

Structured Interviews

Cognitive task analysis (CTA) interviews are used to elicit knowledge from clinicians on their background to learn point of view, work activities, information sources on which they rely, and reflections on the challenges they face (Crandall et al. 2006).

Artifact Analysis

Clinicians use cognitive artifacts to capture and share information (Hutchins 2000). These include hard-copy printouts such as sign-out sheets, white marker status boards, and diagnostic and therapeutic equipment displays. They also include personal notes and related items that individuals find helpful, which are not part of the formal information ecology. The research team is collecting de-identified examples of these artifacts that are maintained by and for the group, as well as artifacts that individuals create and use in their work. Both formal and informal artifacts help to understand the inventory of information that the unit develops and uses, which will suggest the content and flow of information that this project's prototype will help to manage.

Research Process

The team began its work by conducting orientation interviews with selected clinicians at the research site. Quality standards described in Table 7.1 that guided our work are shown in italics. The interviews sought information about the BICU in order to develop an interview guide that would be used to organize data collection efforts during field visits. This enabled the team to develop clear statements of the issues and challenges and the outcome of framing activities. Using these, the team could create the rationale for method, settings, and selection of project participants at the research site. Four one-week data collection visits were conducted at the research site every other month, relying on quality control protocols to document interviews and observations, and cross-check the content of data records. Purposeful sampling of participants and settings ensured validity and reliability of the data that were collected during each visit. Each observation period lasted one week and was followed by a refractory period, during which the investigators reviewed notes, recordings, and artifacts. Data analysis results were also used to revise plans and interview guides for later data collection efforts.

Note that there is no entry in Table 7.1 with the italic font. Please check.

Data Collection

A team of four qualified, prepared data collectors traveled to the site for the first data collection visit. They conferred with the Associate PI (located at the research site) on ICU census and plans for clinical activity. Using multiple KE methods to support findings consistency and comprehensiveness, they conducted CTA interviews to account for each role in the clinical care team. They accompanied the clinical team on daily rounds each morning, which were typically held outside of each patient room. During the trip, the team managed the dual requirements for rigor and flexibility by following interview guides, yet taking the opportunity to shadow participants and ask probe questions when the occasion presented itself. The team collected data firsthand by observing the phenomena that occurred while clinicians provided care in the ICU, using the CSE approach to describe the ICU as a work domain and to account for individual and team cognitive activities. They also collected de-identified examples of computer-based and hard-copy artifacts that the staff use in their daily work.

Rounds were recorded using a handheld video camera to capture team interaction and artifact use and were de-identified using a video-editing software. Recordings were made for future reference on how team members use and share information, including reference to artifacts such as sign-out sheets and task lists. When clinicians interacted directly with the patient, the team used audio recordings to capture how information was shared. No video was taken of the patients. When clinicians had time available, two team members conducted a CTA interview following the interview guide that was developed in the initial six months of the project. If the clinicians were not

available during the scheduled team visit, the on-site research nurse would help to organize the interview, and the core team members would participate remotely.

Data Analysis

Data are evaluated using goal-driven selection of qualitative vs. quantitative analysis to extract patterns and themes. The research team gathers for data analysis meetings roughly a month after each data collection visit. The team has experience to detect and elicit patterns through a systematic, purposeful, and documented analysis process. Analysis sessions make possible the insight into what matters in the research setting and why it matters by performing checks on findings credibility, consistency, comprehensiveness, and centrality.

"Analysis sessions make possible the insight into what matters in the research setting..." - edits OK?

Team members prepare by reviewing the data collected from the most recent visit to ensure that each member has a current accurate recollection. This may also include organizing the data and checking to make sure that they are complete and ready to be analyzed. Members assemble as a group in 2–3 day-long sessions over a week to discover what the data mean by looking for central questions, issues, and themes. For example, the interview guide sought information on how team members manage work flow. Data analysis discussion explored observation notes and interview responses for items related to workflow.

The analysis sessions are intense sense-making exercises that use multiple analysis processes and make multiple passes through the data. Qualified team members use interview notes, observation notes, and artifacts to find patterns and themes in the collected data using reliability indices such as intercoder reliability (when and if they are appropriate). The team also looks for related themes, such as whether there is evidence among the data that show how the clinicians identify and reconcile goal conflicts or resolve agendas that do not agree. Team members suggest themes or patterns that seem to occur in the data. Others challenge, modify, or add to the discussion to ensure validity checks on findings. Team members create diagrams, tables, timelines, and storyboards and use other visualization methods to pose, assemble, and reassemble relationships in order to recognize possible patterns among and across data. During these free-flowing exchanges, new insights rapidly evolve and take the team to a new level of understanding.

Keeping track of the logic trail during these sessions can be a challenge. Maintaining the logical connection from data through analyses matters, because each of the requirements that the analyses eventually produce must have a deliberate link to the data from which they were derived. To keep track of these relationships, the team keeps notes that maintain an audit trail to connect data elements to findings to design elements. Without this structure, it is easy to disregard the data, producing a result that is not a set of findings but rather a collective team impression.

By the end of the analysis sessions, the team has deepened their understanding of what they know about the work setting and what occurs there. They also have a clearer sense of what isn't known yet and needs to be included in the plan for the next site visit. Later in the year, further analysis work will code and analyze all interview and observation data to detect themes and barriers and produce requirements for the prototype.

Limitations

Modest project funding made it necessary to study one site, which limits its reliability. The research team was not available on the unit continuously during the study, making it difficult to observe momentary changes in unit activity such as clinician responses to codes. To mitigate that limitation, the research nurse was available at the research site to collect data in the periods between research team visits.

Preliminary Findings

While the project has only been underway for a brief time, the first data collection and analysis sessions made it possible to describe initial findings that include unit activity, the network of care providers, and information sources on which the clinicians rely. These elements amount to an initial inventory of the work setting that the team can build on during subsequent site visits.

Unit Activity

While many activities occur on the unit through 24 h, Table 7.2 shows the essential events that occur regularly each day. Those who are involved in these activities and the information resources they use to perform them start to flesh out a description of the unit.

Through the evening, the bedside nurse and resident both monitor and occasionally provide medication to the patient assigned to their care. From 6:30 to 8:00 a.m., the residents and medical students examine the patients and prepare for formal multidisciplinary rounds. The Assistant Chief Nurse and oncoming bedside nurses hold a safety huddle. Off-going and oncoming bedside nurses review their patient's condition and conduct a handoff. The ICU Chief Nurse reviews the unit population and resource needs, and the unit dietician reviews patient nutrition plans. At 8:00 a.m., the general rounds begin and can last up to two or more hours depending on a number of factors including unit census, patients' condition, and time pressure. From 8:00 a.m. to 2:00 p.m., patients are showered, receive care for their wounds, or are taken to the nearby operating room procedures such as tissue debridement, skin grafting,

TABLE 7.2

BICU Schematic Timeline—Weekdays

Time	Activity	Participants	Information Resource
0000–0645	Patient monitoring, occasional medication	Bedside nurse; resident	Patient monitors
0630–0800	Patient exam, rounds preparation	Resident, medical student	Sign-out sheet; patient health record (PHR), wound flow, radiology images; patient monitors; bedside nurse, off-going resident
0645–0700	Safety huddle	Assistant Chief Nurse, oncoming bedside nurses	Personal notes
0700–0800	Bedside report and physical assessment	Off-going bedside nurse, oncoming bedside nurse	Patient monitors
0700	ICU audit	Assistant Chief Nurse	Personal notes
0700–0730	Metabolic assessment	Dietitian	Excel file; PHR
0800	Patient rounds	Intensivist, burn surgeon, fellow, resident, bedside nurse, charge nurse, medical student, respiratory therapist, occupational therapist, social worker, dietician, psychiatrist	PHR
0800–1400	Shower, wound care	Bedside nurse, wound care team: RN and LVN	Wound flow
0800–1400	Medications	Bedside nurse	
0800–1400	Surgeries	Burn surgeon, OR team	Shadow charts
~1400	Patient exam	Resident	
1200–1300	Lecture	Staff physician, surgical and medical residents, medical students	
~1500	Afternoon rounds		
1530	Plan for wound care the next day	Charge nurse, wound care coordinator	4T assignments sheet

and reconstructive surgery. The remainder of the day includes a lecture for residents/medical students, the resident examination of his/her patient, brief afternoon rounds to review what has been completed from tasks assigned during morning rounds, and an informal discussion between the wound care team leader and the charge nurse to decide patient plans for the next day.

Network

Patients on this BICU typically need care by a variety of specialists, requiring exceptional planning, coordination, and ability to work together. Table 7.3

TABLE 7.3

BICU Patient and Patient Care Staff Roles

Patient	Bedside Nurse	Patient Family	Attending Intensivist	Burn Surgeon	Licensed Social Worker
Head nurse	Occupational therapist	Respiratory therapist	Resident	Medical student	Clinical nurse specialist
ICU nurse	Psychiatric nurse	Unit clerk	ICU director	Charge nurse	Pharmacist
Staff psychiatric nurse practitioner					

depicts many of the roles that need to collaborate to create and manage a feasible plan for patient care across multiple shifts through the week and the weekend. The roles range from the bedside nurse, who serves as a primary care provider and kind of the gatekeeper for patient care by others, to primary care physicians such as the intensivist and burn surgeon, and care specialists such as the respiratory and occupational therapists, those who care for members of the health care team such as the psychiatric nurse practitioner, managers who assist with planning and oversight, and hospital employees off the BICU such as the pharmacist. In a unit that involves as many team members and specialties as this BICU, it can help to focus on a single most important element of the work domain. In this unit, the bedside nurse is closest to the patient and can serve as a focus of attention for the researcher to understand crucial working relationships. Figure 7.1 represents the 31 working relationships in our data that the bedside nurse maintains in daily practice. Among all of these roles, the bedside nurse interacts most with others on the nursing staff, the patients' family and friends, physicians (including physicians of different levels of training and of different specialties), rehabilitation/occupational therapy technicians, and the clinical lab and blood bank.

Information Resources

Prior work by researchers including Xiao et al. (2001), Wears et al. (2007), Nemeth et al. (2006), and Bisantz et al. (2010) has described the role of cognitive artifacts (Hutchins 2000) in the health care setting. These artifacts include physical items that are either personal (e.g., a sign-out sheet or note on a scrap of paper) or informal and used by a group (e.g., marker board), as well as electronic information displays that are local (e.g., equipment information display) or distributed (e.g., information system display; electronic medical record). Figure 7.2 depicts many of the artifacts that the staff relies on to perform individual and team cognitive work each day.

Databases and interfaces to manage them include the PHR, outpatient record, blood glucose management, laboratory culture, nurse scheduling, and radiology images. While used in concert, many of these systems are

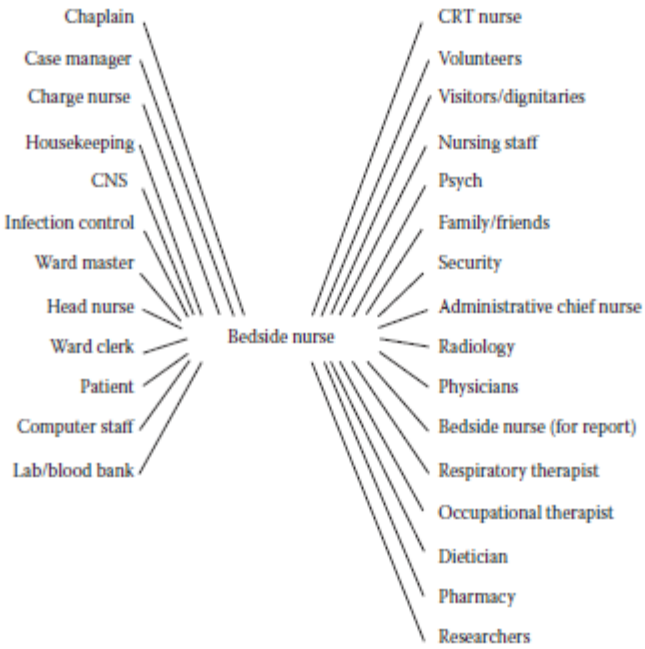

FIGURE 7.1
Initial representation of bedside nurse work relationships. (Copyright © 2013 Applied Research Associates, Inc.)

actually separate. This separation requires care team members to take extra steps and make temporary hard-copy notes to use and transfer information among systems. Other information resources beyond databases include white boards, a daily wound care plan, vital signs flow list, email/cell phone roster, landline phone roster, resident sign-out sheet, and a charge nurse checklist. The strong emphasis on research at the project site has made it possible for clinicians to develop their own formal electronic information sources in addition to the hard-copy artifacts that may be found at other health care locations. The Wound Flow software program makes it possible to identify the location and condition of tissue injury and skin grafts. An Excel file that the unit dietitian has developed makes it possible to accurately track the quality and amount of nutrition that is crucial for burn patient recovery. The Burn Resuscitation Decision Support software enables the staff to accurately manage fluid resuscitation during the critical 48 h following a significant burn injury. The solution that this project creates will need to bring these various parts of this information ecology (Nemeth et al. 2008) together in order to form a cohesive whole for the unit to use. We expect

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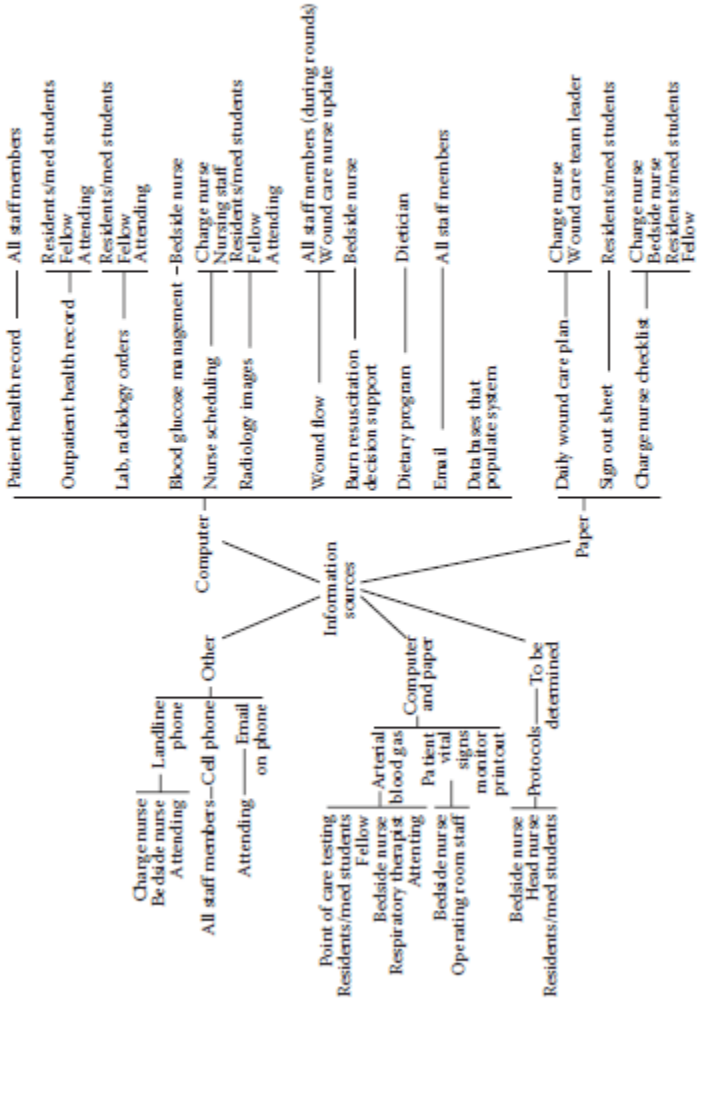

FIGURE 7.2
Information sources that the BICU care providers use. (Copyright © 2013 Applied Research Associates, Inc.)

that using the cognitive aid will enable the unit staff to work together more effectively and efficiently and, as a result, improve patient care effectiveness and outcomes.

Cognitive Work

An initial review of the data indicates that individuals and teams perform a number of macrocognitive (Crandall et al. 2006) activities, which are summarized in Table 7.4. The staff performs *rework* through bridging and work-around strategies to link systems that don't talk to each other in an effort to ensure *information continuity*. For example, the ABG unit is not connected to the database for the electronic PHR. (See Chapter 6 for additional examples, and a proposed model, for tracking ways that information is maintained throughout health care systems.) The dynamic activities on the unit require *negotiation* hourly/by shift/daily among individuals, specialties, and those who have different levels of expertise. *Allocation of resources requires planning and replanning* among and across patients and specialties in *anticipation* of the patient status and needs, and how to meet them through preparation and participation in events.

"Allocation of resources requires planning and replanning among and across patients and specialties in anticipation of the patient status and needs, and how to meet them through preparation and participation in events." - edits OK?

TABLE 7.4

Emergent Themes for Cognitive Work of Burn ICU

Theme	Definition
Rework	Bridging and work-around strategies to link systems that don't talk to each other.
Information continuity	Arterial blood gas (ABG) does/doesn't connect to electronic PHR. An additional volume needs to be created for a very long term care patient.
Negotiation	Among individuals and care specialties, team member levels of knowledge and expertise are dynamic, which requires negotiation by the hour, shift, and day.
Scheduling	Planning and replanning among and across specialties.
Anticipation	Patient status, needs, and how to meet them; preparation and participation in events.
Coordination	Collaboration requires expression of expectations, prioritization, agreement, and recruitment/transfers.
Clarification	Inquiry, sense making, common grounding, to drive down levels of uncertainty and reach an acceptable level of confidence.
Resources	Access, availability, permission, provision, preparation, authority, certification, and use related to equipment, medications, and supplies.
Tasking	Assignment of ICT team members to best match patient needs; based on individual abilities and experience and team needs.
Cross-checking	Identify, confirm, and correct information; problem detection, which may create drag in completing care activities.
Tracking	Account for what needs to be done, whether it has been completed, and what remains to be done.
Gaps	The ability some more experienced team members have to suspect something that is needed is missing.

Collaboration requires the expression of expectations, prioritization, and agreement for staff member recruitment and patient transfers. In order to reach threshold of confidence with which they are comfortable, staff members *clarify* through inquiry, sense making, and seeking common care by reducing uncertainty. Use of *resources* such as equipment depends on its availability as well as permission, provision, preparation, authority, and any required certification to use them. These traits fit what Cook and Woods (2002) have described as the "technical work" in the context of health care. *Tasking* assigns ICU staff members to best match individual abilities/experience and team needs to meet patient needs. Through *cross-checking*, the staff detects problems and identifies, confirms, and corrects information. Their *tracking* efforts account for what needs to be done, whether it has been completed, and what remains to be done. Staff members with the greatest expertise are able to see "gaps," which are, in effect, "what isn't there" but should be.

Challenges

A number of work domain issues shown in Table 7.5 can detract from the time and effort that could be devoted to patient care. Our project team considers each issue from the viewpoint of whether the cognitive aid could help to either mitigate or eliminate them. Nurses fill gaps in the *limited orientation* that residents and float (off unit) nurses receive, which takes time from patient care. Due to *lags in information* timing of information on labs and blood cultures, staff members need to rely on verbal orders (referred to as "on the sly") that are not fully socialized or shared and can result in care delays. *Bedside nurses reconcile conflicts between* patient care needs and technology protocols, guidelines, policy, and regulations. *Procedural drag* results from the need for transcription and work-arounds due to system organizational gaps. The need for clinician *reliance on memory* provides the researcher with a marker for failure, as technology fails to support the needed work. *The long-term story of the patient/big picture is lost*, because trend information and understanding are lost or degraded over a long term of care. *Reliance on verbal exchanges* makes the flow of information porous, brittle, erratically shared, and less reliable. The *authority gradient* between junior and more senior staff members encourages passivity with regard to concerns and impedes sharing. *Common grounding accuracy* suffers from underspecification, requiring confirmation, verification, and clarification. It is not always clear *who has the "Con?"* (has the lead) among specialists during procedures when care quality is high, but no individual takes accountability to assure results. *Timing* issues can result in poor coordination and stale information, such as when a procedure was performed. Without *salience* to bring it to the clinician's attention, important patient information such as "stat" orders is lost in homogenous information displays. Software *usability/access/usefulness* issues result in difficulties in being able to use it, having the knowledge it

TABLE 7.5

Emergent Themes of Barriers and Challenges to Effective Care

Issue	Definition
Limited orientation	Residents and float RNs receive limited orientation to the unit. RNs provide orientation, which takes time from patient care.
Lags in information, medications, labs, and blood	Reliance on verbal orders "on the sly" (informally) that are not fully socialized or shared; creates consistent care delays.
Bedside nurse reconciles conflicts	Technology protocol, guidelines, policy, regulations, and patient care needs require choices to be made.
Procedural drag	The need to create work-arounds and bridging tactics to fill the gap between incompatible systems slows down work efficiency.
Reliance on memory as a failure marker	Technology fails to support necessary work, causing clinicians to rely on memory for continuity (e.g., action items not completed by afternoon rounds not carried through to the next day).
Story of the patient/ big picture is lost	Incremental views of patient status are not synthesized into a whole picture; particular concern for patients in BICU for extended periods.
Reliance on verbal exchanges	Information flow is porous, brittle, not shared, or reliable.
Authority gradient	Encourages passivity with respect to expressing concerns.
Common grounding accuracy	Under specification, needs for confirmation, verification, clarification all affect ability of clinicians to develop consensus.
Action/who has the "Con?"	Numerous well-qualified clinical specialties collaborate but lack of clarity regarding who is leading a particular procedure (e.g., ECMO).
Timing	Lack of synchrony can result in stale information (e.g., when the procedure was performed).
Salience	Great deal of information that is presented homogenously. Information that is most relevant is difficult to find (e.g., "Stat" orders are not evident).
Usability/access/ usefulness	Systems cannot be used without requisite operator knowledge, certain access requirements.
Organizational issues = drag	Compliance with administrative reminders detracts from patient care.

requires to use it, and being able to enter data accurately. Compliance with *organizational issues* such as administrative reminders creates drag for clinician efficiency.

Discussion

The ICU Work Setting

ICU patients present clinical teams with unique challenges and complex combinations of life-threatening injuries and illnesses. Care for this patient

population is necessarily multidisciplinary and includes many specialties. Care providers across these clinical areas must collaborate to develop treatment plans, assess progress, and refine or change treatment plans and modes.

Clinician decisions are only as good as the information that is available when they are made. The daily work on the unit requires representations that serve as a map of the ever-changing environment of work that must be successfully navigated. Clinical teams that care for ICU patients in the military health care system encounter these challenges as they make diagnostic and therapeutic decisions and share them with colleagues. Decision-making difficulty increases as the number of patients and the severity of their conditions increase. Complexity grows as the number of care providers seeks to make their own unique contribution to a patient's care.

Patient care activities rely on the acquisition, portrayal, and analysis of therapeutic and diagnostic information from many sources. This creates a complex work setting that is composed of multiple independent agents. All interact in various ways according to inconsistent rules in an attempt to adapt to changing conditions. Because of this, the organization's outcomes are unpredictable, but they often follow predictable patterns (Plsek and Greenhalgh 2001).

Other ethnographic studies also revealed insights into acute care settings. For example, Fackler et al. (2009) used CTA to identify cognitive aspects of critical care practice in two academic ICUs and identified broad categories of cognitive activity: pattern recognition; uncertainty management; strategic vs. tactical thinking; team coordination and maintenance of common ground; and creation and transfer of meaning through stories. Anders et al. (2012) used a simulator-based experiment to evaluate ICU nurses' ability to detect patient changes using an integrated graphical information display (IGID) compared with a conventional electronic chart-style ICU patient information display. The study found that the 32 ICU nurse samples reported more important physiological information with the novel IGID compared with the tabular display and concluded that information displays should accommodate the diversity of those who are intended to use it.

Novak et al. (2012) found that medication administration intersects with other organizational routines, and IT-enabled changes to one routine lead to unintended consequences in its intersection with others. Introducing IT can be improved by nurses who provide technology-use mediation before and after the rollout of a new health IT system. Their efforts can help others to better understand the relationship between IT introduction and changes in routines.

In addition to operational complexity, our research into reporting health care adverse events using CSE methods (Nemeth et al. 2006) has also revealed technical, social, political, and legal forces. Each influences acute care settings such as the ICU, which are typically uncertain, interrupt driven, saturated, and contingent.

Uncertain: Clinicians must treat widely varying patient populations. Time pressure can force clinicians to make decisions based on information that can be insufficient or ambiguous. Field studies using CSE methods can discover initiatives that clinicians have developed to minimize uncertainty.

Interrupt driven: Interruptions create breaks in clinicians' task-oriented work (Chisholm et al. 2000), and when they occur during diagnosis and treatment, they can degrade or defeat attempts to treat patients. Work domain study using CSE methods can identify gaps in care continuity, detect how clinicians allocate limited attention reserves, and produce tools such as cognitive artifacts that maximize patient care opportunities.

Saturated: Facilities and staffs typically run at or near capacity. With little margin of time or resources to spare, clinicians have to develop strategies to cope with variations in care demand. Work domain studies using CSE can reveal discontinuities that exist in the match between resources and demand, such as late shifts, and unexpected surges in care demand.

Contingent: The process of care depends on the patient, including presenting symptoms, documentation of history, response to therapy, expected trajectory of treatment, compliance, and more. CSE methods can be used to discover how care providers create, monitor, and adjust multiple contingencies in order to achieve as satisfactory and expedient an outcome as possible for patients.

In addition, distraction, complexity, remote influences, and consideration make health care human subjects research a particular challenge.

Distraction: Many activities are performed by a variety of clinicians in the vicinity of each other. This makes it easy to be distracted by phenomena that are not necessarily key features of the work domain.

Complexity: Acute care settings have many complex activities that occur at the same time. This is particularly true in an ICU.

Remote influences: Care team members can be distributed across various locations and across time. Not all activity that matters occurs within view or in the immediate recall of those whom the researcher interviews.

Consideration: Patients in the BICU are typically fragile as a result of some trauma. This calls for the researcher to have an adequate sensitivity to care providers, patients, and the patient's family members.

All of these influences form the context in which clinicians perform their cognitive work. The CSE approach makes it possible to describe the domain and individual and team activity in it to transform findings into requirements that serve as the basis for a prototype cognitive aid.

Communication among Care Team Members

Team communication creates, and is created by, the work context. CSE can be used to reveal the context and worker behaviors that lead to understanding communication needs and how to support them. This contrasts with the more traditional information engineering approach that assumes that

understanding comes simply from the faithful uninterrupted transmission of data (Feldman and March 1981; Stohl and Redding 1987). Care provider expectations differ on communication content, form, relevance, and value of its completeness.

Interventions based on CSE methods can benefit team communication. For example, Grome et al. (2009) found that co-creative development workshop helped surgical team representatives to create and adapt preoperative briefing content and structure, as well as measures to assess the briefing's effect on teamwork, communication, and patient safety.

The entry "Nemeth and Cook (2013)" is not included in the reference list. Please provide missing information in the references.

Nemeth and Cook (2013) used CSE to identify barriers that can erode the quality and reliability of health care communication that this project addresses.

Difficulties in communication. Health care and the information that is needed to provide it are typically complex and demand accuracy in order to avoid misinterpretation.

Confusion of responsibility. Interwoven relationships among care providers, units, departments, and institutions can result in confusion over who is responsible for a patient's care.

Lack of, or variable availability of, good information resources. Even with sophisticated information technology available, system failure or incompatibility can result in images and reports being mislabeled, misunderstood, swapped, late, misidentified, or unavailable.

Work environment pressures. Care provider efforts to cope with workload demands and time pressure can result in a kind of "shorthand" that edits information in order to be efficient.

Lack of standards or training. Clinical specialties and institutions can vary in the way they go about practices such as handoffs, resulting in the potential for misperception.

Aptitude. Patients and family members may find it hard to understand the information that is conveyed through written, verbal, and graphic health care communication.

Attention. Understanding and context are essential to effective communication. Simple transmission (e.g., a "data dump") does not guarantee that others understand what is provided or can correctly put it into context.

Attitude. Clinician empathy may yield a number of benefits, including patients reporting more about their symptoms and concerns, increased physician diagnostic accuracy, patients receiving more illness-specific information, increased patient participation and education, increased patient compliance and satisfaction, greater patient enablement, and reduced patient emotional distress.

Reader et al. (2008) found that team structure and individual roles and stature have significant effect on ICU communication, and a difference in status appears to influence how communication is perceived. The "authority gradient" barrier mentioned in Table 7.5 may be related to this issue.

Through the use of CSE, the cognitive aid that this project produces will need to help the ICU staff to overcome these potential barriers.

The Role of CSE

The use of CSE methods makes it possible for the researcher to "get in" at the right level of detail. Too general a study will miss the nuances and refinements that clinicians create in order to make their work possible. Too detailed a study may collect great amounts of data but will also miss the broader patterns that make insight possible. Studies of such a complex domain require repeated visits in order to reveal the deeper aspects of what occurs. These are what have been referred to as the "messy details" of technical work (Nemeth et al. 2004). The researcher needs to learn about real-world settings that involve the organized activities of daily life (Garfinkel 1967). Real-world settings are stubborn, though, and do not easily reveal themselves (Blumer 1969).

Research can be basic (a search for general principles), applied (adapting general findings to classes of problems), or clinical (related to specific cases). Most design research is clinical because time and budget allow for little else (Friedman 2000). CSE methods can be used to negotiate the gap between applied and clinical research.

CSE in Health Care

Recent work on collaboration has produced distributed cognition and joint cognitive system models that can be used to better understand health care as a collective enterprise. The use of CSE to identify and describe all ICU elements, including clinicians, information, and artifacts, can identify system gaps. Addressing gaps can lead to authentic improvement in performance and outcomes. For this reason, CSE is particularly well suited to the discovery of phenomena in complex real-world settings.

The entry "Hutchinis 1995" is not included in the reference list. Please provide missing information in the references.

Distributed cognition (Hutchins 1995) is the interaction of individuals, artifacts, and the environment. Practitioners must rely on this to prevent the formation of gaps in the continuity of care (Cook et al. 2000). This includes transfers between departments, work-cycle shift changes, and information exchanges among professionals from different fields of practice. Clinicians in an ICU comprise a joint cognitive system that can modify its behavior and decision making on the basis of experience in order to maintain order (Hollnagel and Woods 1983). The daily work of the clinician requires representations that serve as a map of the ever-changing environment of work that must be successfully navigated (Rasmussen et al. 1994). Individual elements of information vary enormously in the length of time that they are reliable, and their value depends on their context. What is represented and how it is represented should depend on the cognitive work it is intended to

"Practitioners must rely on this to prevent the formation of gaps in the continuity of care (Cook et al. 2000)." Edits ok?

support. Furthermore, the partial and overlapping interaction among clinical specialties in the ICU lends itself to additional gaps in care continuity and the misadventures that can result.

Validity

Nemeth et al. (2011) recommended four ways to verify whether results from qualitative studies such as this ICU research project are valid. Findings must be credible, consistent, comprehensive, and central.

Credible. Do findings "ring true" to SMEs and others who work in the domain?

Consistent. Do findings replicate across interviews and across incidents?

Comprehensive. How general are the findings? To what range of tasks and settings do they apply? Can boundaries be identified, and can those limitations be stated?

Central. Do findings speak to cognitive issues that *matter* for performance based on SME judgments, research literature, and other sources?

Studies that meet these criteria are more likely to pass validity tests when solutions are evaluated.

Aspects of Resilience

Knowledge gained through the use of CSE about the nature of work as it is actually done can help to contribute to the system's ability to adapt when confronted with unforeseen challenges—to be more *resilient* (Hollnagel et al. 2006). Recent writing in resilience engineering has identified a number of system characteristics that contribute to system resilience. This knowledge can improve their ability to operate despite significant challenges such as changes in the type, rate, and volume of care. Three characteristics that CSE can assist include being self-aware, the ability to identify and apply resources, and the ability to adapt to surprise.

Self-Aware

The "cottage industry structure of the national healthcare delivery system" results in "disconnected silos of function and specialization."(Reid et al. 2005, pp. 12–13) Acute and ambulatory care patients require coordinated care that is provided by multiple distributed care providers. Their care also calls for the coordination and integration of many functions and specialized areas of knowledge over time. Yet connectivity, integrated care, and coordination are inadequate nationwide at all stages of illness treatment. An estimated 60 million patients in the United States suffer from two or more chronic

The entry "Reid et al. 2005" is not included in the reference list. Please provide missing information in the references.

conditions and are particularly affected by the disconnection among clinical care specialties. The ability to reveal the nature of work domains by using CSE can start to mitigate this significant and widespread issue.

Able to Identify and Apply Resources

Skills, supplies, equipment, and facilities are routinely assembled to perform each procedure. CSE can be used to document work processes and what influences them. That can lead to insight into how these configurations are developed and managed, what goes well, and where misadventures can occur.

Able to Adapt to Surprise

We have shown in prior publications (Nemeth et al. 2007; Cook and Nemeth 2010) how health care organizations respond to events, particularly misadventures. More often than not, the response attempts to isolate the cause and declare that it will not happen again. These efforts stop the exposure to risk. However, they also stop the learning that can inform us how systems have difficulty adapting. The use of CSE makes understanding what goes right, and what occasionally does not, a routine learning process that can improve the ability to adapt.

Summary

We need to learn what people actually do in health care teams and how to design work processes and systems based on that knowledge. This calls for an approach that reveals the true nature of work as it is actually done, not as it is intended to be done. CSE serves that purpose well.

Early data collection and analysis activity in our BICU research have identified the network of those who care for patients, the information sources they use, and the flow of patient care activity. Continued visits are expected to deepen the understanding of interrelationships among clinicians, how they address and resolve conflicts such as different agendas, the information sources and their use, and cognitive activities for each of the clinical specialties and roles. Results from this first year of study will be used to develop requirements for decisions that clinicians make. Requirements and use cases will provide the basis for a prototype to be developed and evaluated in the project's second and third years.

The well-designed valid cognitive artifact that results from our use of CSE is intended to support individual and team cognitive work, which is expected to improve the reliability and efficiency of clinical care for patients.

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Appendix E. CCS USAISR 5-9 January 2015 Visit Interface Review Notes Data Review

9 February 2015

CCS January USAISR Visit Data Review

During the week of January 5-9, 2015, the CCS team visited USAISR, San Antonio. The trip had been planned to conduct an initial usability assessment of the Module One software prototype. The assessment would follow task scenarios, collecting quantitative data (e.g., time to complete task) and qualitative data (e.g., subjective report on ease of use). Findings would be used to improve layout, terminology, and navigation.

A week before the visit, the USAISR staff asked that the visit agenda be changed. Issues in data mapping from Essentris to the interface resulted in the prototype being less finished than USAISR preferred. USAISR asked to change from a usability assessment to a series of informal reviews by members of the clinical staff. Without a research design to structure or tabulate the sessions, there was no means to derive findings based on systematic observation and empirical analysis. As an alternative, the ARA team sought results that could be used to improve the software prototype. Through multiple passes and an in-person review session, the ARA team developed ten categories using thematic analysis.

In contrast to rigorously vetted data from Year One, the comments are individual opinions. Some corrections are helpful, such as the medications listing in the Patient View. Many of the remaining comments indicate personal preferences and speculations about what might be.

The usability assessment originally scheduled for January 2015 is planned for October 2015, when Module Two is completed.

Contents

Views

Date	*Data*	*Role/Page*
1.5	Maybe we need to show whether the patient is on ECMO	Attending
1.5	So I'm looking at the Summary View. What the hell does the Summary View tell me? So, clinicians, I don't ever read this [15:42] by the way. So the reading here [looking at descriptive/explanatory text on the screen above the timeline], I'm looking for what this is telling me without reading something, it's a graph, it should tell me what it tells me without having to read a piece of information. So, how do I know, without reading this, if this is showing me 8 hours? [16:00]. I guess it's here? No, that doesn't have hours. The only way for me to know if this is showing me 8 hours, is this [16:06]. Non-starter, that won't help me, that'll get me confused.	Attending
1.5	[Summary view] Then I'm trying to figure out how I would manipulate that period of time. So let's see if I can hit a month [16:18]. Can't hit a month. Three months? Can't hit any of those, none of those are functional… yet. I guess the only way to do this, with this. Now this, down here [16:30] makes me think I'm looking at 1, 2, 3, 4, 5 days maybe? That's hard for me to figure out because this only has three dates so I was initially thinking that this was three days' worth of data but it's not, this is actually before 31 December… 30, 31, and this is not the same as this [16:52], I think we've already identified that as an issue. And then I want to scale down here, there's no data so I don't know what I'm really looking at [17:00]. So I think if I'm trying to do… I'm coming into work today, what I'd want to see when I first walked in maybe the last 24 hours [17:11], probably the initial step, maybe, with the ability to check maybe… I don't know, through shift, which is 12 hours. So maybe through shift, that's probably a lot of information, 24 hours… so 12 hours, 24 hours, 72 hours, one week. And then, putting your own date range, or something like that [17:39]. "All"… that reset everything. It's interesting, year-to-date, ah… that's what that's doing [17:46], it's making it from the 1st of January because it's a new year. We don't think in terms of year to date in the ICU, maybe from admission to now would be useful. So it could be 12 hours, 24 hours, 72 hours, something like that, one week, and then the entire admission, those might be reasonable slices.	Attending
1.5	I would really like to build a cardiovascular/physiologic screen of all this stuff. One that has cardiac, respiratory… where's GU? GU is renal. Looks like GU is renal. I don't recall that in our original view of this that there was… this was a slightly different layout. At one point in time they talked about having within this section, maybe different layouts of images, and the ability to have different ways of …representing information within the same… this is the parent, right? These are children [JP Video 2, 0:05]. I think what I was looking for right here, with the table view of urine output, inputs/outputs at the same time. The input side and the output side, and that part of Essentris is actually pretty good, we get inputs and outputs. We'll probably have to scroll through the entire thing, which is painful. It'd be better just to have it all right here. Again, I don't know I would look at that graphically so I'm not sure if this was a graph that would really work well because you're looking at what the volume of urine output is here vs. what the volume inputs are here. So I'm not sure with a graphic here would ever work for an ins and outs screen in the renal section. [JP Video 2, 0:52].	Attending
1.5	There's also added here now, a Rehab and Wound Care section but I see a lot of stuff down here [JP Video 2, 15:00] so why couldn't those be tabs? Why couldn't we go all the way around maybe? Go all the way around the corner, that'd be kind of neat, maybe.	Attending

Date	*Data*	*Role/Page*
1.5	We know what some of the important things are to capture and maybe we need to put separate tags along these lines [on the timeline in Patient View, top of central screen]. Line changes, any procedures, anything that goes up in the Team View—procedures, dressing changes, ORs, intubations, extubations, those are procedures. Bronchs don't always come up that much, I mean even when we do them, they're procedures, and they aren't captured on the Boards at all. Intubations and extubations get captured on that board. Big dressing changes, the first post-op dressing change. Wound back down gets captured. Line changes are captured. ORs obviously are captured… Code would be captured. I haven't had one since we've had team meetings [unintelligible, 4:35]. All right, I haven't looked at this yet, by the way, in this view, I'm not sure what to do with it. But I'm going to look at wound care [JP Video 2, 4:48].	Attending
1.5	[RE: how frequently CCS pulls from Essentris and how CCS data is refreshed, JP Video 2, 7:22] will be okay. You might put a little "refresh" button on there and people will remember that. So what I'm looking at this medication thing [JP Video 2, 7:30] it's not helpful. And the reason for it is because there's no consistency with the way the information is displayed. I don't know what the right answer is here but the information needs to be displayed in a consistent fashion. If the intent of this is just to show the medications they are on, then get rid of everything else. All that information should go away. If the intent is to show drug and dose, great, it should be drug-dose. if the information is drug-dose-timing, like every 'x' number of hours, then it should be drug-dose-time. And I think the reason for that might be is we're pulling from the medications list as opposed to pulling from the Order section. So, it would probably be better to pull this list from the Orders section for meds because the Orders section has those things pulled out in a more consistent fashion. And then maybe what you do is what's important? My assumption is that if the order is written, they're getting the drug. That's my assumption, right? So, maybe what we'd do then is the check on it, is look into the chart and if it wasn't given, if this med was… if it's a brand new med, you might have to do a rule, the rule might be, "Order just acknowledged," right? There's an acknowledgement time? If the acknowledgement time is less than… I don't know… one hour ago, don't look for held meds, or don't look for doses. Right? Don't look for med being given. However, if the acknowledgement is older than that, look and see if drug has been given at the appropriate time. And it might be even more… probably even more important than that, if it's a once a day drug, and it was written today, you probably don't look back more than 24 hours. Right? To see if it was given or not. If it's an every six-hour drug, you'd have to look back six hours ago, and if it hasn't been given within the last six hours, you might spend another seven hours, and then it would say, "not given yet," and make it red. [JP Video 2, 9:35]. Right? Or if it has "held" in there like this [JP Video 2, 9:38], then you might make it yellow, or something like that. There's a rule related to the order frequency with which it's being given. And then, all of a sudden, this becomes meaningful, right? Because now I'm looking at the current medication list, it's not just the medications that were given in the last 24 hours, and when they were given. The current medication list, and then I'd know whether it was missed or held, just by looking at it—red or yellow. I think my assumption is that it's given. I'm not sure if that's… you'd want to do if it's an exception to the rule. The rule is that it's given… So maybe what you do is you can hover over it and get more information about it.	Attending
1.5	Why don't we just interact with the patient list by going to Unit View? Just make people get into the habit of going to Unit View	Attending
1.5	The Scheduling View now. I keep trying to…. Whoa, why'd that go away [JP Video 2, 34:30]? Well, it automatically creates a new thing as soon as I left click anywhere. That's kind of interesting, I can make lots of things. Oh it doesn't, it moves it.	Attending
1.6	This [Patient] view doesn't benefit me, as I already know 95% of this from Essentris (as a bedside nurse).	CRN-1

Date	*Data*	*Role/Page*
1.6	Patient View looks like a good thing for rounds	CRN-1
1.6	[Rounds CRN] It should be one list – just like the paper version.	CRN-2
1.6	[Rounds CRN] If I can have an input view on the cardiac – If I can put those task, orders, and checklist items – filter them into categories based on systems.	CRN-2
1.6	[Rounds CRN] What if I can stay on my System View, input the tasks, and then they get added.	CRN-3
1.6	Q. What's the meaningful interval for poling Essentris? A. During rounds, every 15 minutes	CRN-2
1.6	For the bedside nurse, I don't see the value of anything but the Unit View, because I know all the data before the system even imports it.	CRN-3
1.6	I like the individual Patient View and System View for rounds. If you can put the checklist data input screen on the systems page.	CRN-3
1.6	I think the Unit View would be helpful to me as a CN to tell me where to go next, instead of seeing who is screaming.	RN-8
1.6	What is important in ICU is the last 24 hours. No more than that.	RN-4
1.6	To me, Unit View – not all our patients are burns either – can we change TBSA on here?	RN-5
1.6	Q. When you talk about having a merged view like that, what is the value? A. It gives me sort of a trend, I can look at his sedation level versus the medication he's on, and monitor his blood pressure at the same time.	RN-4
1.6	Is there a way to indicate when they will go to surgery?	RN-5
1.6	No activity is going to have a fixed schedule, you have to be ready for replanning, based on the entire unit schedule.	RN-6
1.7	I like comorbidities – gives a quick overview on the unit. Tasks and comorbidities are big things. If you could tie meds in there too.	RN-1
1.7	Is therapy PT? Maybe there should also be PT. I guess we could put 'surgeon' – just because the surgeon could be someone different – and they are very involved with the care of the patient (Potential additions to Team Care Team Manager View).	RN-3
1.7	Also, if patient is under initial resuscitation. Can we get burn navigator in here? Initial Resuscitation, date of burn, time of burn…	RN-5
1.7	A1C – not sure if that belongs in there [Endo view]	RN-7
1.7	Jeff: Any other role should be listed? Interviewee: Charge nurse – especially if it is linking to pager. The only people not on here are social worker, chaplain…	RN-8
1.7	Okay, so instead of [just] ventilator [e.g., yes/no] – CPAP – 10 and 5 – so, was it ordered, check. If you delete it, why was it deleted?	RN-9
1.7	ID widget – I don't know if we would need just central line – or all the lines – PICC lines tend to have infection on Day 19 (discussed in rounds the other day) – this might be important.	RN-10
1.8	It might be like my phone, if you put too many different things on it, it will slow down. And this looks like this might be redundancy – what's the difference between checklist and task list?	Unit Admin-RN-4
1.8	In this view, I agree, it would be more helpful for the orders to be flagged for more important things. For the task list, it would be more important to follow our current structure. For the checklist, I don't need to see routine things like bath, oral care. I need to see CT, things that we need to get done today. I feel like the best use of this tool would be like a dashboard – a quick look. What the CN needs to know – who has the risk of dying today? What I need to know – are their vital signs out of range – based on what their alarms parameters are set at perhaps – maybe we can customize that per patient	Woundcare advanced practice nurse-5
1.8	You need a dashboard for the CN. The bedside nurse will have a different view – they need a deep dive. The CN needs to be able to prioritize among patients to decide who is getting care from which nurse. So multiple layers of dashboards – resident/nurse each responsible for 1-2 patients – but the CN needs a much more global view.	Melvin—nurse leader-5

Date	*Data*	*Role/Page*
1.8	I have general information about the wounds up here [Unit View]. It [TBSA] seems at first like a very important thing – but for an individual patient it might not be – some patients have severe inhalation and no wounds at all.	LVN Wound Care Group Session-7
1.8	[Unit View] As a quick look – okay they're doing okay – Maybe color-coded. R-Y-G	RN-1
1.8	[Unit View] Tells me number of days in the ICU – comorbidities – but what is way more important than comorbidities are lines, antibiotics…	RN-1
1.8	Would this have color codes for different roles – rehab, physicians, etc.?	Nursing leader-Melvin-5
1.8	Maybe turning or transferring should be added to the list?	LVN Wound Care Group Session-7
1.8	Maybe if the most critical [patients] are in red – like at the top (header on Unit View) Or post a butterfly if we have a purple butterfly issue?	LVN Wound Care Group Session-8
1.8	I don't know the significance of the red arrow [Unit View]	RN-audio only
1.8	What is meant by 'tasks'? I'd rather see who is at risk on the floor [Unit View].	RN-audio only
1.8	Instead of co-morbidities it would be better to have a visual cue about the condition of the patient – like a red box if trouble. Even if not my patient is [helps me remain aware of what is happening on the unit]. And what if it is an emergency message?	RN-audio only
1.8	[Patient View] If I am the Nurse, we want the temperature. We always check temperature, HR, BP, Map. Same with the doctor, we want urine output, but we don't have that here – *finds GU view* – can we put this [urine output] at the top? For example, I have a patient that doesn't have a Foley, but I want to see urine output –	RN-1
1.8	[Patient View] Yes, customize by patient [response to J asking if he was suggesting that provider customization of screen is desirable] – So does this show all of the labs? Critical or abnormals – results – is this visible? If it's one click away, that is easier. Doctor comes in and wants to see the results, so that would be helpful. Event History – it's not clickable right now? That would be good.	RN-1
1.8	[Patient View] So on the med list, say you administer the Heparin, has that one fallen off, or does it stay there? From our standpoint, on this woundcare detail, maybe a place where we can know what kind of dressings they are in? Like say if they are in 5% sulfamylon solution, that is helpful to know – also where.	LVN Wound Care Group Session-7
1.8	[Patient View] Blood Gasses – Lactate needs to be on there – not on respiratory view. Also need oxygen index for respiratory.	
1.8	On the CRT – it downloads from Essentris, right? [GU view] Maybe we need to see the type of fluids? It has everything except the type of fluids.	LVN Wound Care Group Session-7
1.8	[Patient View] Lactate – should be in both places – Respiratory and Cardiac. These are lab values?	LVN Wound Care Group Session-7
1.8	[Patient View] Meds – It will also help, doctors give vanco multiple times, it will help to know which time it's being administered (e.g., third time vanco)	RN-2
1.8	[Patient View] Labs: And then, pending labs – can we see that here? Like for example, I have a patient that's bleeding, the Dr. orders labs every 4 hrs. times 4, and if it shows in the main screen, we will not miss it…It will be awesome if we have pending labs ahead of time – and abnormal results.	RN-2

Date	*Data*	*Role/Page*
1.8	[Patient View] Essentris has iplots – you can pick two variables and plot them over time – being able to readjust the view would be helpful. Where is woundcare pulling from? There may need to be a disclaimer there – it's not always updated [WoundFlow] everyday, so this might not be as up to date as what is shown in rounds. It would be helpful to pull from Essentris op-days (from op note) This information is not necessarily in WoundFlow… It would be really helpful for someone to look at it, and check if the orders are correct everyday. Someone could check, yes, they've been checked and are ready to go. I think the diagram would be helpful [WoundFlow] – do they still have full thickness – do they have fungus – wound cultures? any pending cultures? Maybe we pull the wound cultures – could be in both places (also in ID).	Woundcare advanced practice nurse-6
1.8	[Patient View] So it's really great that there's trends. The only downside is there is no scale on these. So, for example, the Lactate graphic – there's no scale attached, so 4.07 doesn't tell me definitively where it is – I take it back – now that I see that [mouse over] that's good, I can see the numbers. It would be helpful to have numbers on either end, so at a quick glance I can get that information. I try to limit rounds on a patient to 10 minutes each, so I don't necessarily have time to mouse over to see the numbers. I'm having a hard time figuring out what this graphic represents [event history].	Resident-9
1.8	*[reviews GU view, then ID view]* I see Foley days, but not central line days – if it just reported days in (on the summary screen) – that would be helpful.	Resident-9
1.8	The key section has labs, but none of the other views. If I'm trying to do lab rounds, I would like a view where I could see all the labs at once, not have to click through all the systems. When I round on someone in the morning, a screen like this would be all I need. A list of meds with the active dose along with the past 24 hrs. I usually look for vitals with the trend – although these are slow to load up, and a bit hard to interpret at a glance. I also look for labs, and if they have been done, and radiology and if it's been done, as well as EKG – Vigileo – Catheter.	Resident-9
1.8	[Patient View] I won't use this—I already know it because I enter it in Essentris and I can't change it here. Might be useful if I was monitoring someone else's patient. If screens were dynamic and I could see and [interact] with them in one spot, it would be useful. If I could enter data. Maybe useful for nurse to nurse handoff to have this display because I'd have to flip through screens on Essentris. A screen that shows similarity between patients from the past would be helpful.	RN-audio only
1.8	My bigger point is, I think we should tailor it, even though every individual needs to have input, I need, in reality, the attending is the key person for the day – so I think we need to tailor, focus things to making sure that those positions have the easiest view of what's going on. It's always the attending, and CN that need to have a good grasp of what's going on. If they don't know what's going on, you're going to have a catastrophic failure.	Unit Administrator RN-5
1.8	[Care Team Manager] I like being able to know where the team is, if I need to talk to someone.	RN-audio only
1.8	[Schedule View] I think it [dynamic adjustment of schedule] is [of value] – one patient in room 7 was supposed to have woundcare, but they are scheduled to go to CT, and that would have been helpful to know so we can schedule our time.	LVN Wound Care Group Session-8
1.8	[Schedule View] Offhand I would say no [not of value]– if my patient census is 10-15 – going in and making these changes is unlikely to happen. If it is created for me by someone, that might	Resident-10
1.8	[Schedule View] Nurses don't have time to constantly change schedule. Maybe the unit secretary could change. The schedule is too fluid to [capture accurately] on this. Don't want a useless screen. [Sense: How could anyone keep up with this?]	RN-audio only
1.8	For TBSA – it would be neat if we can pull this and see the entire picture.	RN-1
1.8	[WoundFlow] Oh, cool – so the color-coded image of the body, that will be helpful. [RN suggesting that the color-coded image be provided]	RN-1
1.8	Medication – if it's due – 11a.m. if there is medicine due – if it could line up there.	RN-2

Date	*Data*	*Role/Page*
	…the last hospital I worked at had Meditech – it would show medications due in the next hour.	
1.8	[The charge nurse task list] It's a visual reminder of what's happening – it would be better if we have (to the right) what's going on with the patient. If I see the information, we can go ahead and prepare what's necessary in the room.	RN-3
1.8	Finds messages window within the CRN view – this is really cool because we can track information about what we need to relay to the family, that we might forget through the day Is this like a Chat Room?	RN-3

Messaging & Notice icons

Date	*Data*	*Role/Page*
1.5	RE: TBSA—"How do I know if this is 27%, if they're still 22% open, but it's Day 30… right… this patient might actually be sicker right now than this person who is 72% TBSA with 67% open on Day 5, right? So that's really important to know which day it is [since injury/admission to unit?]. Even better to know, some relationship between what percentage open they are and what day it is. So, if you're three weeks into it and you're still very, very open, that's more of a problem than if you're on Day 3. If you're six weeks into it and you're still the same percentage, or bigger, than you were originally, that's even worse.	Attending
1.5	[Can you write a message?] I don't know… I'm not interested in this. [7:43] I can't write a message with that. [7:54] I can re-open this window by right clicking on 'messages' and hitting 'open window,' that's a problem. Yes. So I want to go back, let's see if I can go back this way [8:29]. I can, that's cool. So now it's bouncing, why on earth is it bouncing? It's bouncing at me and there's nothing there. Oh, and you know what?	Attending
1.5	[Message alert] I think it should never… I don't know… the bouncy things make me think this is the most important thing on this screen when it's bouncing up and down. It bounces when you change screen whether you have a message or not.	Attending
1.5	What I was thinking when I hit this messaging channel [JP Video 3, 2:10] was it would just take me to the messaging channel and I would do something else. But I have to actually hit "messaging channel" and then a new patient. A two-step process for something… I don't know… it seems like it should be directed to a generic messaging window and then you could pick the patient. I don't know. What happens here [JP Video 3, 3:19] is it seems like this gets really long, and if I look at this, I can interact with this faster because I don't lose my place. Right? Any time you go back to this, if it's this, then if I'm looking for messaging then I have to go find it again. And that' s my take on it [JP Video 3, 3:40]. **But aren't you already in messaging?** … so if you're in messaging right now, right? [JP Video 3, 3:50], and if I open this again, the first thing I'm going to see is the messaging thing is going to be expanded. Right? But I don't want to do messaging, I want to do CRN deal. Right? So, now I'm thinking about clicking this [JP Video 3, 4:00], but then I have to click it and then I have to go find my patient again. It seems like I would somehow or another click this and I would go to a rounds CRN view, and then I'd pick the patient that I wanted somehow. It should always come up like this maybe first, maybe that would be more palatable because then I can just get used to where I'm going to look, click it, find it, as opposed to it is expanded to when I first get to it. That just seems like it's not as…	Attending
1.6	Messaging is helpful, as I can communicate without leaving the patient room, for instance, if I'm concerned with a resident placing a line.	CRN-1
1.6	Messaging system, though, is an immediate, easy way to get the message off, rather than having to get up and walk around the unit.	CRN-1
1.6	The overview, with messaging would be more important, as it allows for an overview of what is going on on the unit so the bedside nurse could communicate something without leaving the room – can't leave someone while they are doing a procedure.	CRN-1
1.6	Messages are really important to get a quick view.	RN-5
1.7	It seems like a lot of potential messages – You wouldn't really want to put something urgent on here – how do you know you're going to get a rapid response. I would think this would be more of like, family was just in – if anyone's around, they'd like to talk. I would be afraid if it's urgent that someone doesn't get the message.	RN-11
1.7	These lines are all connected – between patients – I can see where it would be confusing – maybe different colors would be helpful.	RN-11
1.8	Would be helpful to send a message to a member of the team – so you can talk to one person. [Liked idea of sending message directly through Care Team Manager – to an individual.]	LVN Wound Care Group Session-8
1.8	Is this messaging part of the medical record?	Resident-

Date	*Data*	*Role/Page*
	That's what pagers are for. The official thing to do is phone someone in. Other hospitals have textpage built in. Can be unreliable. Last thing you want to do is leave a message for someone and not be sure if they got it. [Also expressed concerns over legal implications of messaging.]	10
1.8	If people rely on this to communicate with me, I need to be notified that message has come. I don't sit in front of the computer—I could miss this. Same is true of orders on Essentris—there is no 'bing'. The problem with it binging is that it competes with a lot of other things. If I come out of room to respond to a bing it better not be, 'Hey girl, let's go to lunch.'	RN-audio only
1.8	This creates another opportunity to have someone send you a message that you miss and then say, 'You should have [x] because I sent you a message.'	RN-audio only
1.8	Our RN team has one pager, so you can't page us. We communicate mostly by 'boarding house call.' It is not easy to get a hold of people.	RN-audio only
1.8	This is awesome, this would be a new thing for me – I don't know how this would alarm in my computer, so I would know there's a new message. Unless we have a pager? [RNs do not have pagers]	RN-3
1.8	Yes – for me that would be really helpful, if I could do this through my computer – and get a hold of the respiratory therapist, for example.	RN-3

Task list

Date	*Data*	*Role/Page*
1.5	RE: tasks and co-morbidities: I hover over them, I left click on it. You say, "Okay, here are the tasks that are due." Right? Or, maybe just simple right here, "Incomplete task." That's the rule here. Right click on it, open up Tasks, you go to Tasks, and it shows you the whole task listing. So it's a lot easier to get to it	Attending
1.5	[salient to machine learning] Right, just incomplete tasks. Very simple list, something like that. And that gets back also into our conversations about this ability to build knowledge about what clinicians are interacting with. So, if the first thing they do is they always go to the task list, I click on this and I want to see what the tasks are that are due, maybe that's the first window we should start pulling up for people. Right? If the first thing that they do is hover over the medications, and the only one they ever hover over is norepinephrine, well maybe we need to pull the norepinephrine information into this box, somehow, someday, because they always look at that. I mean every time norepinephrine is there, they always click on it, 100% of the time. That would be meaningful information for us to capture. So we get this constant linking, clicking, and those kinds of things, again, I think that's useful [JP Video 2, 14:52].	Attending
1.5	We're letting people add their own checklist items? **[Josh or Tony] This is something we could link to the role-based system but right now it's not.** I think we've seen a good display of what the Checklist tool should mostly look like. [JP Video 2, 19:59] I guess I have to go to entry in order to put in something here. **[Josh or Tony] You can add.** I feel like there should be a box here for me to start typing in. I can't put anything in these things, you have to do an "add" first [JP Video 2, 20:15]. That's too many clicks in my mind to get to this point. People say, "I don't really want to do something." This is a test… [inserting into box]. [JP Video 2, 20:32]. I can't add my own person. So what happens if a person who is on this is not somebody who is not on the list. Do you have to be in the list? **This once again goes back to the whole CAC authentication, if there's CAC thing, it's going to have everyone with a CAC card.** So there are tasks that are not specific to any individual person and I will tell you that the team right now does not think about assigning any task to any person, totally foreign concept, they don't do it at all. There's no assignment. Right Chris, by and large? Rarely, comes up now and then, "Are you going to do that?" "Yes." "Okay." That's how tasks assignment goes. They're assumed… I don't know what to do with this, assigned and categories as well. My anxiety is if we have an assignment here, right… I don't know that people will know what to do with it yet. [JP Video 2, 24:08]. I mean even if they say, "Well, who is it assigned to?" I don't know… so that's a part of the research question, I suppose. **[Admin-RN] Yes, would it be better, for starters, just to put the roles there [JP Video 2, 24:26].** Or put both. I mean let somebody assign it to a person, or a role. I don't know. The category thing, also, I don't know what to do with. I also found out that I can just get rid of my tasks without ever saving it by accident. [JP Video 2, 24:47] I accidentally closed it, right, so… can I 'Ctrl-Z' it, no I can't 'Ctrl-Z' it. **[?] Does the 'Save' feature work?** Yes. So I went along here and I hit this back [unintelligible, JP Video 2, 25:05], so I don't know why I would have this button AND a clear button since they do the same thing, apparently. I want to be able to edit it [text].	Attending

Date	*Data*	*Role/Page*
1.5	The blue one [task on schedule] is covering it up so you can't even see the orange one [JP Video 3, 00:07]. I don't care, I just moved it. I didn't want to edit it, that's it, it was driving me crazy. Every time you touch it, if it's just a move, it opens up another screen. Got it. [JP Video 3, 00:22]. Okay, it seems like also the same color may not want to overlap the same thing because I didn't change that color, that was blue before, it changed to green. Anyway, it seems like, theoretically, these people will be doing the same… it'll be the same person doing this and this, and you probably can't be in two places at once, I would think. Again, I think the idea of being somehow or another to copy it, to copy and paste it somewhere else so you can build, or whatever you want to do, would be kind of nice.	Attending
1.6	What's important is what's created as the task list. This gives me a roadmap, even if it's not a current roadmap.	RN-7
1.8	Maybe turning or transferring should be added to the list?	LVN Wound Care Group Session-7
1.8	So it's kinda like a checklist? I think that on the tasklist, if there is a place you can checkoff to show that it got done, that would be helpful.	LVN Wound Care Group Session-7

Color scheme/Layout

Date	*Data*	*Role/Page*
1.5	The first thing that I'm a little disappointed by, we still don't have the right color scheme on here.	Attending
1.5	I see a lot of empty space still; empty space is just lost realty and makes me think that each one of these can be bigger and more readable.	Attending
1.5	I don't know what purple and orange mean. Purple and orange, in medical language, they're neutral colors, I don't know what they mean–royalty and expensive, I don't know.	Attending
1.5	Now, I have all my little arrows back, and everybody is getting better! Good! Now I don't have to work today. [red arrows had been on screen for each room in Unit View then disappeared]	Attending
1.5	This is duplicate data [13:01], Hemoglobin, Hematocrit, I don't need both of these right here [13:05]. RBC is useless, I can't remember the last time I looked at it, except for when I was calculating a red blood cell index of a particular site count. So I don't know why that's here, I just don't remember that being on the individual's screen. White count would probably be important…	Attending
1.5	Maybe we can have INR here [13:29] or something?	Attending
1.5	And really, white blood cell count, even though it's here [13:37], we're not really thinking about it in the HEME section, this should be over in the ID section. Right? White blood cell count ID, should be there.	Attending
1.5	At one point in time we actually had, we thought about having a picture of WoundFlow, an actual picture. Right? A WoundFlow picture of the patient here… [Clarified he did not mean the photo]…the image [graphic of the body]. Right? Because there's live, contextual information there and I don't know whatever happened to that view of this but I think that went away.	Attending
1.5	Again, there's empty space, it seems like we should be able to make things bigger overall	Attending
1.5	What else can I start working on here [top left of Patient View with red arrow, purple and orange bands]. [15:12] Again, I think this should be consistent between all the different views, should be the same way of looking [between the Unit View showing these data and the Patient View]. So if I were to go back to the actual [15:22]… this view, you would think that it should look the same as this [15:24].	Attending
1.5	All right, where's that heart rate? I want to see heart rate. Heart rate 60 [19:43], and then upper limit. **Maria: Can you change it?** Make it 60. Well, this should make it do something, right? 60 and 60, that's the same value [19:54]. ***[U] That must have been a typo.*** Well I know but even if it is, let's make this 70. **So it'd be an alert of some sorts is what you're saying, perhaps? [20:00]** Wait a minute I want to see what happens when you change it. Because, theoretically, it's heart was 104, it didn't do anything yet. It changes to a minus. [?, 20:18]. All right, so theoretically, it did something here, I'm guessing, but I can't tell. As soon as I touch this [graph, 20:32], it gives you this little pop up which obscures my entire view of my trend, this has to go somewhere else, I can't see what that frame is. I'm assuming that it did something up here. This is annoying. [20:44]. There needs to be a time thing on this or a right click on it or something that makes this, "Ahh!"	Attending

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1.5	That's what I was trying to figure out. So we've got some values here [27:29], let's look at these values. I am not easily able to correlate what these heart rates mean with these values over here [27:43]. So am I actually at 24 hours right now? That's a problem, I don't know if I'm actually looking at 24 hours' worth of data. It looks like I'm not looking at 24 hours' of data, this looks like a lot more than 24 hours' worth of data. Is it more than 24 hours' worth of data? [28:01]	Attending
1.5	The Ventralizer [32:19], we made these things [putting the cursor of graphs in Patient View], the ability to turn them on and off. So I can go back and look at them on and off, and see relationships. That's another way of taking care of real estate so if I want to look at this one, great.	Attending
1.5	[JP Video 2, 12:29] that's kind of cool, I just discovered that Task and Co-morbidities change colors when I hover over them, but they don't do anything when I click on them. **[RN-admin] So it's just an undeveloped feature?]** **[Josh or Tony] Yeah.** It's cool though.	Attending
1.5	Eventually having the co-morbidities here would be super cool though because these co-morbidities constantly affect how these patients heal, or don't heal, and to be able to quickly know and I'm new on this patient, I've never had this patient before, what's the patient's past medical and surgical history? To be able to click on that and have that listed would be cool.	Attending
1.5	I would really like to build a cardiovascular/physiologic screen of all this stuff. One that has cardiac, respiratory… where's GU? GU is renal. Looks like GU is renal. I don't recall that in our original view of this that there was… this was a slightly different layout. At one point in time they talked about having within this section, maybe different layouts of images, and the ability to have different ways of …representing information within the same… this is the parent, right? These are children [JP Video 2, 0:05]. I think what I was looking for right here, with the table view of urine output, inputs/outputs at the same time. The input side and the output side, and that part of Essentris is actually pretty good, we get inputs and outputs. We'll probably have to scroll through the entire thing, which is painful. It'd be better just to have it all right here. Again, I don't know I would look at that graphically so I'm not sure if this was a graph that would really work well because you're looking at what the volume of urine output is here vs. what the volume inputs are here. So I'm not sure with a graphic here would ever work for an ins and outs screen in the renal section. [JP Video 2, 0:52].	Attending
1.5	There's also added here now, a Rehab and Wound Care section but I see a lot of stuff down here [JP Video 2, 15:00] so why couldn't those be tabs? Why couldn't we go all the way around maybe? Go all the way around the corner, that'd be kind of neat, maybe.	Attending
1.5	We know what some of the important things are to capture and maybe we need to put separate tags along these lines [on the timeline in Patient View, top of central screen]. Line changes, any procedures, anything that goes up in the Team View—procedures, dressing changes, ORs, intubations, extubations, those are procedures. Bronchs don't always come up that much, I mean even when we do them, they're procedures, and they aren't captured on the Boards at all. Intubations and extubations get captured on that board. Big dressing changes, the first post op dressing change. Wound back down gets captured. Line changes are captured. ORs obviously are captured… Code would be captured. I haven't had one since we've had team meetings [unintelligible, 4:35]. All right, I haven't looked at this yet, by the way, in this view, I'm not sure what to do with it. But I'm going to look at wound care [JP Video 2, 4:48].	Attending

Date	*Data*	*Role/Page*
1.5	[RE: how frequently CCS pulls from Essentris and how CCS data is refreshed [JP Video 2, 7:22] will be okay. You might put a little "refresh" button on there and people will remember that. So what I'm looking at this medication thing [JP Video 2, 7:30] it's not helpful. And the reason for it is because there's no consistency with the way the information is displayed. I don't know what the right answer is here but the information needs to be displayed in a consistent fashion. If the intent of this is just to show the medications they are on, then get rid of everything else. All that information should go away. If the intent is to show drug and dose, great, it should be drug-dose. if the information is drug-dose-timing, like every 'x' number of hours, then it should be drug-dose-time. And I think the reason for that might be is we're pulling from the medications list as opposed to pulling from the order section. So, it would probably be better to pull this list from the Orders section for meds because the Orders section has those things pulled out in a more consistent fashion. And then maybe what you do is what's important? My assumption is that if the order is written, they're getting the drug. That's my assumption, right? So, maybe what we'd do then is the check on it, is look into the chart and if it wasn't given, if this med was… if it's a brand new med, you might have to do a rule, the rule might be, "Order just acknowledged," right? There's an acknowledgement time? If the acknowledgement time is less than… I don't know… one hour ago, don't look for held meds, or don't look for doses. Right? Don't look for med being given. However, if the acknowledgement is older than that, look and see if drug has been given at the appropriate time. And it might be even more… probably even more important than that, if it's a once a day drug, and it was written today, you probably don't look back more than 24 hours. Right? To see if it was given or not. If it's an every six-hour drug, you'd have to look back six hours ago, and if it hasn't been given within the last six hours, you might spend another seven hours, and then it would say, "not given yet," and make it red. [JP Video 2, 9:35]. Right? Or if it has "held" in there like this [JP Video 2, 9:38], then you might make it yellow, or something like that. There's a rule related to the order frequency with which it's being given. And then, all of a sudden, this becomes meaningful, right? Because now I'm looking at the current medication list, it's not just the medications that were given in the last 24 hours, and when they were given. The current medication list, and then I'd know whether it was missed or held, just by looking at it—red or yellow. I think my assumption is that it's given. I'm not sure if that's… you'd want to do if it's an exception to the rule. The rule is that it's given… So maybe what you do is you can hover over it and get more information about it.	Attending
1.5	Why don't we just interact with the patient list by going to Unit View? Just make people get into the habit of going to Unit View	Attending
1.5	The blue one [task on schedule] is covering it up so you can't even see the orange one [JP Video 3, 0:07]. I don't care, I just moved it. I didn't want to edit it, that's it, it was driving me crazy. Every time you touch it, if it's just a move, it opens up another screen. Got it. [JP Video 3, 0:22]. Okay, it seems like also the same color may not want to overlap the same thing because I didn't change that color, that was blue before, it changed to green. Anyway, it seems like, theoretically, these people will be doing the same… it'll be the same person doing this and this, and you probably can't be in two places at once, I would think. Again, I think the idea of being somehow or another to copy it, to copy and paste it somewhere else so you can build, or whatever you want to do, would be kind of nice.	Attending
1.6	It would be helpful if the HR, CVP, etc. were across the page.	RN-5
1.7	Where the patient is, it fades off too much (hard to read patient name on Unit View). Headings should be darker (on patient Care Team Manager)	RN-1 RN-3
1.7	It says current orders here – I don't – the row function on this – is not fluent to me. It flows, but – A color change would work better. If we just change the colors. Expansion and spacing would help make the meds view less jumbled.	RN-1
1.7	These lines are all connected – between patients – I can see where it would be confusing	RN-11

Date	*Data*	*Role/Page*
	– maybe different colors would be helpful. (Messaging screen on Unit View.)	
1.8	Comorbidities are again not so important. Current Orders – it shows all 166 right now – at least 80 of these are not important to me – but if there are new antibiotics or new CRT orders, that's very important. IF those could be flagged, that might be important. [Col. Melvin chimed in on this—Maybe anything within the last 4-hour window.] [Sarah woundcare APN added Sarah: Maybe they can be categorized by type.]	Unit Admin-RN-4; Nurse leader (Melvin); woundcare advanced practice nurse
1.8	So things discussed in rounds can be added as we're discussing them? Like with a tablet for the CN? So maybe the tasklist be driven by orders by physicians, and the checklist represents the priorities for the day.	Melvin—nurse leader-4
1.8	…If you had flags on important orders (meds) you could almost get rid of items over here (task list).	Unit Admin RN-4
1.8	In this view, I agree, it would be more helpful for the orders to be flagged for more important things. For the task list, it would be more important to follow our current structure. For the checklist, I don't need to see routine things like bath, oral care. I need to see CT, things that we need to get done today. I feel like the best use of this tool would be like a dashboard – a quick look. What the CN needs to know – who has the risk of dying today? What I need to know – are their vital signs out of range – based on what their alarms parameters are set at perhaps – maybe we can customize that per patient.	Woundcare advanced practice nurse-5
1.8	You need a dashboard for the CN. The bedside nurse will have a different view – they need a deep dive. The CN needs to be able to prioritize among patients to decide who is getting care from which nurse. So multiple layers of dashboards – resident/nurse each responsible for 1-2 patients – but the CN needs a much more global view.	Melvin—nurse leader-5
1.8	Do we have consents? Is the patient a falls risk? The key safety things that everyone needs to know – that are Joint Commission things.	Woundcare advanced practice nurse-5
1.8	I have general info about the wounds up here [Unit View]. It [TBSA] seems at first like a very important thing – but for an individual patient it might not be – some patients have severe inhalation and no wounds at all.	LVN Wound Care Group Session-7
1.8	[Unit View] As a quick look – okay they're doing okay – Maybe color-coded. R-Y-G	RN-1
1.8	[Unit View] Tells me number of days in the ICU – comorbidities – but what is way more important than comorbidities are lines, antibiotics…	RN-1
1.8	Would this have color codes for different roles – rehab, physicians, etc.?	Nursing leader-Melvin-5
1.8	Maybe if the most critical [patients] are in red – like at the top (header-Unit View) Or post a butterfly if we have a purple butterfly issue?	LVN Wound Care Group Session-8
1.8	I don't know the significance of the red arrow [Unit View]	RN-audio only
1.8	[Patient View] If I am the Nurse, we want the temperature. We always check temperature, HR, BP, Map. Same with the doctor, we want Urine output, but we don't have that here – *finds GU view* – can we put this [urine output] at the top? For example, I have a patient that doesn't have a Foley, but I want to see urine output.	RN-1

Date	*Data*	*Role/Page*
1.8	[Patient View] So on the med list, say you administer the Heparin, has that one fallen off, or does it stay there? From our standpoint, on this woundcare detail, maybe a place where we can know what kind of dressings they are in? Like say if they are in 5% sulfamylon solution, that is helpful to know – also where.	LVN Wound Care Group Session-7
1.8	[Patient View] Blood Gasses – Lactate needs to be on there – not on respiratory view. Also need oxygen index for respiratory.	LVN Wound Care Group Session-7
1.8	On the CRT – it downloads from Essentris, right? [GU view] Maybe we need to see the type of fluids? It has everything except the type of fluids.	LVN Wound Care Group Session-7
1.8	Medication – if it's due – 11a.m. if there is medicine due – if it could line up there. ……the last hospital I worked at had Meditech – it would show medications due in the next hour.	RN-2
1.8	[Patient View] Labs: And then, pending labs – can we see that here – like for example, I have a patient that's bleeding, the Dr. orders labs every 4 hrs. times 4, and if it shows in the main screen, we will not miss it…It will be awesome if we have pending labs ahead of time – and abnormal results.	RN-2
1.8	[Patient View] So it's really great that there's trends. The only downside is there is no scale on these. So, for example, the Lactate graphic – there's no scale attached, so 4.07 doesn't tell me definitively where it is – I take it back – now that I see that [mouse over] that's good, I can see the numbers. It would be helpful to have numbers on either end, so at a quick glance I can get that information. I try to limit rounds on a patient to 10 minutes each, so I don't necessarily have time to mouse over to see the numbers. I'm having a hard time figuring out what this graphic represents [event history].	Resident-9
1.8	[Patient View] Meds *[mousing over, scrolling]* – these look like variations in the dose of Vasopressin, but I don't understand what these numbers mean. The most usefully would be 24 hr. cumulative for a drip, and it's current rate. One downside of the current rate is that it reports in cc, so you have to do math – it would be nice if it told me units/hr., so you don't have to do the calculation. I don't entirely understand – it says it's current meds, but some are listed twice. A brief summary of names and a current dose, and a 24 hr. tally (total administered) would also be helpful. (ideally past 24 hrs. from the current time).	Resident-9
1.8	The key section has labs, but none of the other views. If I'm trying to do lab rounds, I would like a view where I could see all the labs at once, not have to click through all the systems. When I round on someone in the morning, a screen like this would be all I need. A list of meds with the active dose along with the past 24 hrs. I usually look for vitals with the trend – although these are slow to load up, and a bit hard to interpret at a glance. I also look for labs, and if they have been done, and radiology and if it's been done, as well as EKG – Vigileo – Catheter.	Resident-9
1.8	For TBSA – it would be neat if we can pull this and see the entire picture.	RN-1
1.8	[WoundFlow] Oh, cool – so the color-coded image of the body, that will be helpful. [RN suggesting that the color-coded image be provided]	RN-1
1.8	Medication – if it's due – 11a.m. if there is medicine due – if it could line up there. …the last hospital I worked at had Meditech – it would show medications due in the next hour.	RN-2

Medications

Date	*Data*	*Role/Page*
1.6	The [important] medications are Vancomycin, Amicasin (antibiotics) – Heparin, pressors,	CRN-2
1.6	Antibiotics aren't important unless the patient is septic. Usually it's pain meds. Usually I will look at the vital signs flow sheet	RN-8
1.6	Could you divide meds out, put PRNs here, underneath, put the drips? At least sedation meds first, then pressors – I think pain in general is the bigger issue. Pressors are important, but it varies.	RN-8
1.6	I wish that IV meds were separate, so you can have those grouped together – pain meds, pressors, iv meds**,** in that order.	RN-8
1.7	It would be useful to know all the different pain meds, not just narcotics – that might help determine – today versus yesterday. You can also tell, if you are going from one to another – it's easier to calculate. I would want to know how much opioid and other adjuncts they've been getting over the past 24 hours, in order to adjust that. We use some drugs for pain relief and sedation, so there's some overlap. [Reorganization of Medications]	RN-10
1.7	Medications list – would be helpful to see current meds, but you also want to know what they've been on. Is this telling me when this was added, when it was started? It's not clear. Certain medications are only used for so long, and then they fall off, need to be reordered. It would be helpful to have that information.	RN-11
1.7	What we most need are antibiotics, pressors, and pain meds. We tailor that a lot to each patient (Medications widget).	RN-5
1.7	I like comorbidities – gives a quick overview on the unit. Tasks and comorbidities are big things. If you could tie meds in there too.	RN-1
1.8	[Patient View] So on the med list, say you administer the Heparin, has that one fallen off, or does it stay there? From our standpoint, on this woundcare detail, maybe a place where we can know what kind of dressings they are in? Like say if they are in 5% sulfamylon solution, that is helpful to know – also where.	LVN Wound Care Group Session-7
1.8	Medication – if it's due – 11a.m. if there is medicine due – if it could line up there. ……the last hospital I worked at had Meditech – it would show medications due in the next hour.	RN-2
1.8	Meds—So probably the other thing with this one is how often we're going to give the medication. As a nurse, that will give us an idea of how to use our time…so for instance we give a medication every 4 hours, so if the system tells us it's due in 4 hours that would help.	RN-2
1.8	[Patient View] Meds—It will also help, doctors give vanco multiple times, it will help to know which time it's being administered (e.g., third time vanco).	RN-2
1.8	[Patient View] Meds—Here, the heparin, we also give through vent and subcutaneously – give the route and it will help us avoid making an error.	RN-2
1.8	[Patient View] Meds—Here, the heparin, we also give through vent and subcutaneously – give the route and it will help us avoid making an error.	RN-2
1.8	[Patient View] Meds *[mousing over, scrolling]* – these look like variations in the dose of Vasopressin, but I don't understand what these numbers mean. The most useful would be 24 hr. cumulative for a drip, and it's current rate. One downside of the current rate is that it reports in cc, so you have to do math – it would be nice if it told me units/hr., so you don't have to do the calculation. I don't entirely understand – it says it's current meds, but some are listed twice. A brief summary of names and a current dose, and a 24 hr. tally (total administered) would also be helpful. (ideally past 24 hrs. from the current time).	Resident-9

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Graphs/Visual order

Date	*Data*	*Role/Page*
1.5	All right, Wound Care. Nothing showing up here. Post op days, probably useful. So Neuro… neuro is in the wrong spot [14:38]. I'm going back… [unintelligible, 14:40] systems. So the systems go, Neuro, Cardiac, Pulmonary, GI, Renal, Endo, Heme, ID, Tubes/Lines/Drains, that's how it goes on rounds. [Sense—align order of these items on screen with the order they are addressed on rounds.]	Attending
1.5	So I'm looking at the Summary View. What the hell does the Summary View tell me? So, clinicians, I don't ever read this [15:42] by the way. So the reading here [looking at descriptive/explanatory text on the screen above the timeline], I'm looking for what this is telling me without reading something, it's a graph, it should tell me what it tells me without having to read a piece of information. So, how do I know, without reading this, if this is showing me 8 hours? [16:00]. I guess it's here? No, that doesn't have hours. The only way for me to know if this is showing me 8 hours, is this [16:06]. Non-starter, that won't help me, that'll get me confused.	Attending
1.5	All right, where's that heart rate. I want to see heart rate. Heart rate 60 [19:43], and then upper limit. **Maria: Can you change it?** Make it 60. Well, this should make it do something, right? 60 and 60, that's the same value [19:54]. ***[U] That must have been a typo.*** Well I know but even if it is, let's make this 70. **So it'd be an alert of some sorts is what you're saying, perhaps? [20:00]** Wait a minute I want to see what happens when you change it. Because, theoretically, it's heart was 104, it didn't do anything yet. It changes to a minus. [?, 20:18]. All right, so theoretically, it did something here, I'm guessing, but I can't tell. As soon as I touch this [graph, 20:32], it gives you this little pop up which obscures my entire view of my trend, this has to go somewhere else, I can't see what that frame is. I'm assuming that it did something up here. This is annoying. [20:44]. There needs to be a time thing on this or a right click on it or something that makes this, "Ahh!"	Attending
1.5	That's what I was trying to figure out. So we've got some values here [27:29], let's look at these values. I am not easily able to correlate what these heart rates mean with these values over here [27:43]. So am I actually at 24 hours right now? That's a problem, I don't know if I'm actually looking at 24 hours' worth of data. It looks like I'm not looking at 24 hours of data, this looks like a lot more than 24 hours' worth of data. Is it more than 24 hours' worth of data? [28:01].	Attending
1.5	This scale issue [29:06] is really weird, too. I don't know what the scale is on this [on graph]. It seems like it should at least take a scale value at the top and the bottom of the blue box [29:13], at a minimum, so you know if you're above or below some value there.	Attending

Date	*Data*	*Role/Page*
1.5	So I previously suggested that what we should do is this is actually not the right layout for graphs. The right layout for graphs is all of them linear across. Right? **What do you mean?** So the heart rate should go from here over to here [30:46]. Blood pressure should go from here all the way over to here. [He is indicating that the first graph on the left, in each row, should extend all the way across the center page view. That is, do not put multiple graphs for different variables side by side across each row.] Just like it does actually in a table, right? As it does on a table, except now it's in a graph form, that's all. And the reason for that is because I'm trying to correlate them. Right? I'm trying to look from this one to this one and I'm trying to follow it, but you're stacking them so that you can see that while this is happening, this is also happening. It's a time thing [31:06]... **What if you run out of space while stacking?** There are groupings that go into this like [unintelligible, 31:32] output, stroke volume, variation, and stroke volume are all part of the same kind of data set. So blood pressure is part of the same data set, heart rate is part of the same data set.	Attending
1.5	[RN ADMIN Looking at Hem data]: So it's actually an interesting point that you [the attending] were making with regards to white blood cell count and that it should be over in ID. Because when you're looking in the labs, or in the lab section, this is how it comes. [Attending]: Right. But it's not how we think about it. Same thing with… you said something about INR or coags and TEG would be on here. The other part, here [JP Video 2, 1:50], is I'm wondering with this somewhat disparate values, these are not the same time scale as the physiologic variables, maybe those should be. You need the ability to look at these in a table view vs. a graph view. Maybe this one needs to be graph and this one needs to be table but right now you can change all of them at once, you can't change them individually.	Attending
1.5	I would really like to build a cardiovascular/physiologic screen of all this stuff. One that has cardiac, respiratory… where's GU? GU is renal. Looks like GU is renal. I don't recall that in our original view of this that there was… this was a slightly different layout. At one point in time they talked about having within this section, maybe different layouts of images, and the ability to have different ways of …representing information within the same… this is the parent, right? These are children [JP Video 2, 0:05,]. I think what I was looking for right here, with the table view of urine output, inputs/outputs at the same time. The input side and the output side, and that part of Essentris is actually pretty good, we get inputs and outputs. We'll probably have to scroll through the entire thing, which is painful. It'd be better just to have it all right here. Again, I don't know I would look at that graphically so I'm not sure if this was a graph that would really work well because you're looking at what the volume of urine output is here vs. what the volume inputs are here. So I'm not sure with a graphic here would ever work for an ins and outs screen in the renal section. [JP Video 2, 0:52].	Attending
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1.5	We know what some of the important things are to capture and maybe we need to put separate tags along these lines [on the timeline in Patient View, top of central screen]. Line changes, any procedures, anything that goes up in the Team View—procedures, dressing changes, ORs, intubations, extubations, those are procedures. Bronchs don't always come up that much, I mean even when we do them, they're procedures, and they aren't captured on the Boards at all. Intubations and extubations get captured on that board. Big dressing changes, the first post op dressing change. Wound back down gets captured. Line changes are captured. ORs obviously are captured… Code would be captured. I haven't had one since we've had team meetings [unintelligible, 4:35]. All right, I haven't looked at this yet, by the way, in this view, I'm not sure what to do with it. But I'm going to look at wound care [JP Video 2, 4:48].	Attending

Date	*Data*	*Role/Page*
1.5	[RE: how frequently CCS pulls from Essentris and how CCS data is refreshed, JP Video 2, 7:22] will be okay. You might put a little "refresh" button on there and people will remember that. So what I'm looking at this medication thing [JP Video 2, 7:30] it's not helpful. And the reason for it is because there's no consistency with the way the information is displayed. I don't know what the right answer is here but the information needs to be displayed in a consistent fashion. If the intent of this is just to show the medications they are on, then get rid of everything else. All that information should go away. If the intent is to show drug and dose, great, it should be drug-dose. if the information is drug-dose-timing, like every 'x' number of hours, then it should be drug-dose-time. And I think the reason for that might be is we're pulling from the medications list as opposed to pulling from the order section. So, it would probably be better to pull this list from the Orders section for meds because the Orders section has those things pulled out in a more consistent fashion. And then maybe what you do is what's important? My assumption is that if the order is written, they're getting the drug. That's my assumption, right? So, maybe what we'd do then is the check on it, is look into the chart and if it wasn't given, if this med was… if it's a brand new med, you might have to do a rule, the rule might be, "Order just acknowledged," right? There's an acknowledgement time? If the acknowledgement time is less than… I don't know… one hour ago, don't look for held meds, or don't look for doses. Right? Don't look for med being given. However, if the acknowledgement is older than that, look and see if drug has been given at the appropriate time. And it might be even more… probably even more important than that, if it's a once a day drug, and it was written today, you probably don't look back more than 24 hours. Right? To see if it was given or not. If it's an every six-hour drug, you'd have to look back six hours ago, and if it hasn't been given within the last six hours, you might spend another seven hours, and then it would say, "not given yet," and make it red. [JP Video 2, 9:35]. Right? Or if it has "held" in there like this [JP Video 2, 9:38], then you might make it yellow, or something like that. There's a rule related to the order frequency with which it's being given. And then, all of a sudden, this becomes meaningful, right? Because now I'm looking at the current medication list, it's not just the medications that were given in the last 24 hours, and when they were given. The current medication list, and then I'd know whether it was missed or held, just by looking at it—red or yellow. I think my assumption is that it's given. I'm not sure if that's… you'd want to do if it's an exception to the rule. The rule is that it's given… So maybe what you do is you can hover over it and get more information about it.	Attending
1.5	**[RN-admin] Like pain medicine, that might be a better example. When was the last time the patient got morphine?** If it's a PRN end drug. So if you hit "PRN" maybe the rule for that is different. You look at the PRN drug and you say, "When was the last PRN drug given?" It'll show you something.	Attending

Date	*Data*	*Role/Page*
1.5	**[RN-admin] It's just somewhere there are some PRNs?** **[Josh] Yes, if you look at the second one from the bottom there [10:50], like all that three lines of blue text, that's straight from that one field in the database.** And that's okay, I think, because it's going to come the same way out of their order. It's going to look just like that. What I'd do is, again, I think we need to make it cleaner, this is too messy to look at. So this might be the medication list [JP Video 211:12]. Again, you might have a green, red, or yellow, if you want to prevent information at this level. But then maybe you hover over it, or you left-click on it, and it shows it. That may be another way of doing this, if we separate out left-click and right-click. Maybe left-click turns this box on, left-click turns it off. If I want to get some more information about it, I can right-click and do something with it. I kind of like that idea, left click turns it on/off, makes it go away. [JP Video 2, 11:42] what's that value? Click. Oh, that's what that value is. Click, I don't need that any more. That'd be great. And same thing over here [JP Video 211:49], you might be able to left click it, it pulls up more information about it, left click, it turns off.	Attending
1.5	What I was thinking when I hit this messaging channel [JP Video 3, 2:10] was it would just take me to the messaging channel and I would do something else. But I have to actually hit "messaging channel" and then a new patient. A two-step process for something… I don't know… it seems like it should be directed to a generic messaging window and then you could pick the patient. I don't know. What happens here [JP Video 3, 3:19] is it seems like this gets really long, and if I look at this, I can interact with this faster because I don't lose my place. Right? Any time you go back to this, if it's this, then if I'm looking for messaging then I have to go find it again. And that' s my take on it [JP Video 3, 3:40]. **But aren't you already in messaging?** … so if you're in messaging right now, right? [JP Video 3, 3:50], and if I open this again, the first thing I'm going to see is the messaging thing is going to be expanded. Right? But I don't want to do messaging, I want to do CRN deal. Right? So, now I'm thinking about clicking this [JP Video 3, 4:00], but then I have to click it and then I have to go find my patient again. It seems like I would somehow or another click this and I would go to a rounds CRN view, and then I'd pick the patient that I wanted somehow. It should always come up like this maybe first, maybe that would be more palatable because then I can just get used to where I'm going to look, click it, find it, as opposed to it is expanded to when I first get to it. That just seems like it's not as…	Attending
1.6	What's helpful are graphs, rather than numbers. A trend on a graph is more meaningful then a specific number.	CRN-1
1.6	I see benefit to graphs and trends because most people are visual.	CRN-1
1.6	It's intuitive that I look at those graphs first, and then scroll down quickly.	RN-4
1.6	[merged trend graphs] It gives me sort of a trend, I can look at his sedation level versus the medication he's on, and monitor his blood pressure at the same time.	RN-4
1.7	**Jeff: How would you improve the trend display?** Interviewee: I would put BP, SBP, and MAP all together.	RN-12
1.7	The labels – sepsis, ID, CRT blends in – needs to be more prominent (in CRN Rounds view).	RN-2
1.8	[Patient View] If I am the Nurse, we want the temperature. We always check temperature, HR, BP, Map. Same with the doctor, we want urine output, but we don't have that here – *finds GU view* – can we put this [urine output] at the top? For example, I have a patient that doesn't have a Foley, but I want to see urine output –	RN-1

Date	*Data*	*Role/Page*
1.8	[Patient View] Yes, customize by patient [response to J asking if he was suggesting that provider customization of screen is desirable]– So does this show all of the labs? Critical or abnormals – results – is this visible? If it's one click away, that is easier. Doctor comes in and wants to see the results, so that would be helpful. Event History – it's not clickable right now? That would be good.	RN-1
1.8	On the CRT – it downloads from Essentris, right? [GU view] Maybe we need to see the type of fluids? It has everything except the type of fluids.	LVN Wound Care Group Session-7
1.8	Lactate – should be in both places – Respiratory and Cardiac. These are lab values?	LVN Wound Care Group Session-7
1.8	Medication—if it's due – 11a.m. if there is medicine due – if it could line up there. …the last hospital I worked at had Meditech – it would show medications due in the next hour.	RN-2
1.8	Meds—So probably the other thing with this one is how often we're going to give the medication. As a nurse, that will give us an idea of how to use our time…so for instance we give a medication every 4 hours, so if the system tells us it's due in 4 hours that would help.	RN-2
1.8	The key section has labs, but none of the other views. If I'm trying to do lab rounds, I would like a view where I could see all the labs at once, not have to click through all the systems. When I round on someone in the morning, a screen like this would be all I need. A list of meds with the active dose along with the past 24 hrs. I usually look for vitals with the trend – although these are slow to load up, and a bit hard to interpret at a glance. I also look for labs, and if they have been done, and radiology and if it's been done, as well as EKG – Vigileo – Catheter.	Resident-9

Patient ID widget

Date	*Data*	*Role/Page*
1.5	The original version of our widgets, we talked about this previously, had the room numbers that were actually in the Patient ID widget, because it's part of their ID in many clinicians' minds.	Attending
1.5	Again, the original ID, which I'm pretty sure had these room numbers as part of the ID because, again, if I'm thinking about it. Honestly, I don't remember what this patient's name is, almost ever, during their hospitalization. I remember this is the 65% burn in Room 5, and I'm not the only clinician who is that way ***So does that become an issue, you said that patients move rooms frequently?*** Yes. Um, yes and no. Again, it does… So, the answer is yes. When I see the same patient in a new room, I'm like, "wait a second, is that the person who was in that room before?" And then the answer, "Ah, okay, now I have it." And I re-file them. So, yes, that happens with people.	Attending
1.5	[RN ADMIN Looking at Hem data]: So it's actually an interesting point that you [the attending] were making with regards to white blood cell count and that it should be over in ID. Because when you're looking in the labs, or in the lab section, this is how it comes. [Attending]: Right. But it's not how we think about it. Same thing with… you said something about INR or coags and TEG would be on here. The other part, here [1:50 JP Video 2], is I'm wondering with this somewhat disparate values, these are not the same time scale as the physiologic variables, maybe those should be. You need the ability to look at these in a table view vs. a graph view. Maybe this one needs to be graph and this one needs to be table but right now you can change all of them at once, you can't change them individually.	Attending
1.6	[PT Identifier] There is a benefit to the Comorbidities – medical history. If I leave rounds to take care of the patient, and I missed three tasks, then I could click on tasks and see what was discussed on rounds.	CRN-2
1.6	Q. What if we could show an acuity score? A. Doesn't matter to me. All my patients are 6s – until they are ready to go to 4 East it doesn't mean a thing.	CRN-1
1.6	Comorbidities is nice – I don't always look at it immediately, but it would be nice.	RN-7
1.8	Okay, so this is from 5 Jan., [ID widget] that would be very valuable. I'm assuming we have to determine how long we're going to keep this data? A week, a month? Melvin: If you're pulling all that data, and a patient has been on unit 95 days, that's a lot of data. Melvin: I might not want to see all 90 days [for everything], but if it's an ID issue, I might need to see all 90 days. Jimmy: If we're pulling from Essentris, does it keep it, or does it dump that once I change dates? Because theoretically you could have some data change from two days ago, and it affected data, I'm assuming it would update from Essentris?	RN unit admin and RN leadership-6
1.8	*[reviews GU view, then ID view]* I see Foley days, but not central line days – if it just reported days in (on the summary screen) – that would be helpful.	Resident-9

Quick picture/No hunting

Date	*Data*	*Role/Page*
1.5	RE: TBSA—How do I know if this is 27%, if they're still 22% open, but it's Day 30… right… this patient might actually be sicker right now than this person who is 72% TBSA with 67% open on Day 5, right? So that's really important to know which day it is [since injury/admission to unit?]. Even better to know, some relationship between what percentage open they are and what day it is. So, if you're three weeks into it and you're still very, very open, that's more of a problem than if you're on Day 3. If you're six weeks into it and you're still the same percentage, or bigger, than you were originally, that's even worse.	Attending
1.5	I'm on [Patient] 1 now. [11:00]. Color is not too bad in this, a little bit different from what we had originally. I don't know, something about sharp lines aren't as nice as the rounded lines that we had.	Attending
1.5	What I'm to do right now [2:24] is I'm trying to figure out which patient is the sickest. I'm just trying to look. I would think that this view would give me some understanding of which patient is the sickest and all the colors right now.	Attending
1.5	Again, the original ID, which I'm pretty sure had these room numbers as part of the ID because, again, if I'm thinking about it. Honestly, I don't remember what this patient's name is, almost ever, during their hospitalization. I remember this is the 65% burn in Room 5, and I'm not the only clinician who is that way ***So does that become an issue, you said that patients move rooms frequently?*** Yes. Um, yes and no. Again, it does… So, the answer is yes. When I see the same patient in a new room, I'm like, "wait a second, is that the person who was in that room before?" And then the answer, "Ah, okay, now I have it." And I re-file them. So, yes, that happens with people.	Attending
1.5	At one point in time we actually had, we thought about having a picture of WoundFlow, an actual picture. Right? A WoundFlow picture of the patient here… [Clarified he did not mean the photo]…the image [graphic of the body]. Right? Because there's live, contextual information there and I don't know whatever happened to that view of this but I think that went away.	Attending
1.5	What else can I start working on here [top left of Patient View with red arrow, purple and orange bands]. [15:12] Again, I think this should be consistent between all the different views, should be the same way of looking [between the Unit View showing these data and the Patient View]. So if I were to go back to the actual [15:22]… this view, you would think that it should look the same as this [15:24].	Attending
1.5	So I'm looking at the Summary View. What the hell does the Summary View tell me? So, clinicians, I don't ever read this [15:42] by the way. So the reading here [looking at descriptive/explanatory text on the screen above the timeline], I'm looking for what this is telling me without reading something, it's a graph, it should tell me what it tells me without having to read a piece of information. So, how do I know, without reading this, if this is showing me 8 hours? [16:00]. I guess it's here? No, that doesn't have hours. The only way for me to know if this is showing me 8 hours, is this [16:06]. Non-starter, that won't help me, that'll get me confused.	Attending
1.5	That's what I was trying to figure out. So we've got some values here [27:29], let's look at these values. I am not easily able to correlate what these heart rates mean with these values over here [27:43]. So am I actually at 24 hours right now? That's a problem, I don't know if I'm actually looking at 24 hours' worth of data. It looks like I'm not looking at 24 hours' of data, this looks like a lot more than 24 hours' worth of data. Is it more than 24 hours' worth of data? [28:01]	Attending
1.5	Okay. Here's another thing that we've found in the past. If you're going to do this [run cursor over one graph] [28:37], it has to do it on all of them at the same time. Okay? And the reason for that is because what I'm trying to do right now is I'm trying to see if this guy's heart rate was up, why it was up. I'm trying to understand that.	Attending
1.5	So I previously suggested that what we should do is this is actually not the right layout for graphs. The right layout for graphs is all of them linear across. Right? **What do you mean?** So the heart rate should go from here over to here [30:46]. Blood pressure should go from here all the way over to here. [He is indicating that the first graph on the left, in	Attending

Date	Data	Role/Page
	each row, should extend all the way across the center page view. That is, do not put multiple graphs for different variables side by side across each row.] Just like it does actually in a table, right? As it does on a table, except now it's in a graph form, that's all. And the reason for that is because I'm trying to correlate them. Right? I'm trying to look from this one to this one and I'm trying to follow it, but you're stacking them so that you can see that while this is happening, this is also happening. It's a time thing [31:06]... **What if you run out of space while stacking?** There are groupings that go into this like [unintelligible, 31:32] output, stroke volume, variation, and stroke volume are all part of the same kind of data set. So blood pressure is part of the same data set, heart rate is part of the same data set.	
1.5	Another thing, too, when we start color coding, when you get outside those ranges on the graphic view, theoretically, you would color code the boxes, too. I would think, just like a heat map that we've looked at before, I would think.	Attending
1.5	Eventually having the co-morbidities here would be super cool though because these co-morbidities constantly affect how these patients heal, or don't heal, and to be able to quickly know and I'm new on this patient, I've never had this patient before, what's the patient's past medical and surgical history? To be able to click on that and have that listed would be cool.	Attending
1.5	I would really like to build a cardiovascular/physiologic screen of all this stuff. One that has cardiac, respiratory… where's GU? GU is renal. Looks like GU is renal. I don't recall that in our original view of this that there was… this was a slightly different layout. At one point in time they talked about having within this section, maybe different layouts of images, and the ability to have different ways of …representing information within the same… this is the parent, right? These are children [JP Video 2, 0:05]. I think what I was looking for right here, with the table view of urine output, inputs/outputs at the same time. The input side and the output side, and that part of Essentris is actually pretty good, we get inputs and outputs. We'll probably have to scroll through the entire thing, which is painful. It'd be better just to have it all right here. Again, I don't know I would look at that graphically so I'm not sure if this was a graph that would really work well because you're looking at what the volume of urine output is here vs. what the volume inputs are here. So I'm not sure with a graphic here would ever work for an ins and outs screen in the renal section. [JP Video 2, 0:52].	Attending
1.5	We know what some of the important things are to capture and maybe we need to put separate tags along these lines [on the timeline in Patient View, top of central screen]. Line changes, any procedures, anything that goes up in the Team View—procedures, dressing changes, ORs, intubations, extubations, those are procedures. Bronchs don't always come up that much, I mean even when we do them, they're procedures, and they aren't captured on the Boards at all. Intubations and extubations get captured on that board. Big dressing changes, the first post op dressing change. Wound back down gets captured. Line changes are captured. ORs obviously are captured… Code would be captured. I haven't had one since we've had team meetings [unintelligible, 4:35]. All right, I haven't looked at this yet, by the way, in this view, I'm not sure what to do with it. But I'm going to look at wound care [JP Video 2, 4:48].	Attending
1.5	[RE: how frequently CCS pulls from Essentris and how CCS data is refreshed, JP Video 2, 7:22] will be okay. You might put a little "refresh" button on there and people will remember that. So what I'm looking at this medication thing [JP Video 2, 7:30] it's not helpful. And the reason for it is because there's no consistency with the way the information is displayed. I don't know what the right answer is here but the information needs to be displayed in a consistent fashion. If the intent of this is just to show the medications they are on, then get rid of everything else. All that information should go away. If the intent is to show drug and dose, great, it should be drug-dose. if the information is drug-dose-timing, like every 'x' number of hours, then it should be drug-dose-time. And I think the reason for that might be is we're pulling from the medications list as opposed to pulling from the order section. So, it would probably be better to pull this list from the Orders section for meds because the Orders section has those things	Attending

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	pulled out in a more consistent fashion. And then maybe what you do is what's important? My assumption is that if the order is written, they're getting the drug. That's my assumption, right? So, maybe what we'd do then is the check on it, is look into the chart and if it wasn't given, if this med was… if it's a brand new med, you might have to do a rule, the rule might be, "Order just acknowledged," right? There's an acknowledgement time? If the acknowledgement time is less than… I don't know… one hour ago, don't look for held meds, or don't look for doses. Right? Don't look for med being given. However, if the acknowledgement is older than that, look and see if drug has been given at the appropriate time. And it might be even more… probably even more important than that, if it's a once a day drug, and it was written today, you probably don't look back more than 24 hours. Right? To see if it was given or not. If it's an every six-hour drug, you'd have to look back six hours ago, and if it hasn't been given within the last six hours, you might spend another seven hours, and then it would say, "not given yet," and make it red. [JP Video 2, 9:35]. Right? Or if it has "held" in there like this [JP Video 2, 9:38], then you might make it yellow, or something like that. There's a rule related to the order frequency with which it's being given. And then, all of a sudden, this becomes meaningful, right? Because now I'm looking at the current medication list, it's not just the medications that were given in the last 24 hours, and when they were given. The current medication list, and then I'd know whether it was missed or held, just by looking at it—red or yellow. I think my assumption is that it's given. I'm not sure if that's… you'd want to do if it's an exception to the rule. The rule is that it's given… So maybe what you do is you can hover over it and get more information about it.	
1.5	**[RN-admin] Like pain medicine, that might be a better example. When was the last time the patient got morphine?** If it's a PRN end drug. So if you hit "PRN" maybe the rule for that is different. You look at the PRN drug and you say, "When was the last PRN drug given?" It'll show you something.	Attending
1.5	**[RN-admin] It's just somewhere there are some PRNs?** **[Josh] Yes, if you look at the second one from the bottom there [10:50], like all that three lines of blue text, that's straight from that one field in the database.** And that's okay, I think, because it's going to come the same way out of their order. It's going to look just like that. What I'd do is, again, I think we need to make it cleaner, this is too messy to look at. So this might be the medication list [JP Video 2, 11:12]. Again, you might have a green, red, or yellow, if you want to prevent information at this level. But then maybe you hover over it, or you left-click on it, and it shows it. That may be another way of doing this, if we separate out left-click and right-click. Maybe left-click turns this box on, left-click turns it off. If I want to get some more information about it, I can right-click and do something with it. I kind of like that idea, left click turns it on/off, makes it go away. [JP Video 2, 11:42] What's that value? Click. Oh, that's what that value is. Click, I don't need that any more. That'd be great. And same thing over here [JP Video 2, 11:49], you might be able to left click it, it pulls up more information about it, left click, it turns off.	Attending

Date	*Data*	*Role/Page*
1.5	[salient to machine learning] Right, just incomplete tasks. Very simple list, something like that. And that gets back also into our conversations about this ability to build knowledge about what clinicians are interacting with. So if the first thing they do is they always go to the task list, I click on this and I want to see what the tasks are that are due, maybe that's the first window we should start pulling up for people. Right? If the first thing that they do is hover over the medications, and the only one they ever hover over is norepinephrine, well maybe we need to pull the norepinephrine information into this box, somehow, someday, because they always look at that. I mean every time norepinephrine is there, they always click on it, 100% of the time. That would be meaningful information for us to capture. So we get this constant linking, clicking, and those kinds of things, again, I think that's useful [JP Video 2, 14:52].	Attending
1.5	Why don't we just interact with the patient list by going to Unit View? Just make people get into the habit of going to Unit View	Attending
1.5	[delay in loading—attributed to crosscut] Yes, this is a non-starter right now. [JP Video 2, 18:19]. This kills the tool right now. You can't …	Attending
1.5	We're letting people add their own checklist items? **[Josh or Tony] This is something we could link to the role-based system but right now it's not.** I think we've seen a good display of what the Checklist tool should mostly look like. [JP Video 2, 19:59] I guess I have to go to entry in order to put in something here. **[Josh or Tony] You can add.** I feel like there should be a box here for me to start typing in. I can't put anything in these things, you have to do an "add" first [JP Video 2, 20:15]. That's too many clicks in my mind to get to this point. People say, "I don't really want to do something." This is a test… [inserting into box]. [JP Video 2, 20:32]. I can't add my own person. So what happens if a person who is on this is not somebody who is not on the list. Do you have to be in the list? **This once again goes back to the whole CAC authentication, if there's CAC thing, it's going to have everyone with a CAC card.** So there are tasks that are not specific to any individual person and I will tell you that the team right now does not think about assigning any task to any person, totally foreign concept, they don't do it at all. There's no assignment. Right Chris, by and large? Rarely, comes up now and then, "Are you going to do that?" "Yes." "Okay." That's how tasks assignment goes. They're assumed… I don't know what to do with this, assigned and categories as well. My anxiety is if we have an assignment here, right… I don't know that people will know what to do with it yet. [JP Video 2, 24:08]. I mean even if they say, "Well, who is it assigned to?" I don't know… so that's a part of the research question, I suppose. **[Admin-RN] Yes, would it be better, for starters, just to put the roles there [JP Video 2, 24:26].** Or put both. I mean let somebody assign it to a person, or a role. I don't know. The category thing, also, I don't know what to do with. I also found out that I can just get rid of my tasks without ever saving it by accident. [JP Video 2, 24:47] I accidentally closed it, right, so… can I 'Ctrl-Z' it, no I can't 'Ctrl-Z' it. **[?] Does the save feature work?** Yes. So I went along here and I hit this back [unintelligible, JP Video 2, 25:05], so I don't know why I would have this button AND a clear button since they do the same thing, apparently. I want to be able to edit it [text].	Attending

Date	*Data*	*Role/Page*
1.5	I was thinking it would be really nice to copy this task and put it somewhere else, which I can't really do.	Attending
1.6	it's easier for me to just go back to the vital signs flow sheet, as I have everything in one place. It has the maps,	RN-4
1.6	If I can have an input view on the cardiac – If I can put those task, orders, and checklist items – filter them into categories based on systems.	CRN-1
1.7	I like comorbidities – gives a quick overview on the unit. Tasks and comorbidities are big things. If you could tie meds in there too.	RN-1
1.8	In this view, I agree, it would be more helpful for the orders to be flagged for more important things. For the task list, it would be more important to follow our current structure. For the checklist, I don't need to see routine things like bath, oral care. I need to see CT, things that we need to get done today. I feel like the best use of this tool would be like a dashboard – a quick look. What the CN needs to know – who has the risk of dying today? What I need to know – are their vital signs out of range – based on what their alarms parameters are set at perhaps – maybe we can customize that per patient.	Woundcare advanced practice nurse-5
1.8	You need a dashboard for the CN. The bedside nurse will have a different view – they need a deep dive. The CN needs to be able to prioritize among patients to decide who is getting care from which nurse. So multiple layers of dashboards – resident/nurse each responsible for 1-2 patients – but the CN needs a much more global view.	Melvin—nurse leader-5
1.8	As a quick look – okay they're doing okay – Maybe color-coded. R-Y-G	RN-1
1.8	Maybe if the most critical [patients] are in red – like at the top (header) Or post a butterfly if we have a purple butterfly issue?	LVN Wound Care Group Session-8
1.8	I don't know the significance of the red arrow [on Unit View]	RN-audio only
1.8	What is meant by 'tasks'? I'd rather see who is at risk on the floor [Unit View].	RN-audio only
1.8	Instead of co-morbidities it would be better to have a visual cue about the condition of the patient—like a red box if trouble. Even if not my patient is [helps me remain aware of what is happening on the unit]. And what if it is an emergency message?	RN-audio only
1.8	[Patient View] If I am the Nurse, we want the temperature. We always check temperature, HR, BP, Map. Same with the doctor, we want Urine output, but we don't have that here – *finds GU view* – can we put this [urine output] at the top? For example, I have a patient that doesn't have a Foley, but I want to see Urine Output –	RN-1
1.8	[Patient View] Yes, customize by patient [response to J asking if he was suggesting that provider customization of screen is desirable] – So does this show all of the labs? Critical or abnormals – results – is this visible? If it's one click away, that is easier. Doctor comes in and wants to see the results, so that would be helpful. Event History – it's not clickable right now? That would be good.	RN-1
1.8	Meds—So probably the other thing with this one is how often we're going to give the medication. As a nurse, that will give us an idea of how to use our time…so for instance we give a medication every 4 hours, so if the system tells us it's due in 4 hours that would help.	RN-2

Date	*Data*	*Role/Page*
1.8	Essentris has iplots – you can pick two variables and plot them over time – being able to readjust the view would be helpful. Where is woundcare pulling from? There may need to be a disclaimer there – it's not always updated [WoundFlow] everyday, so this might not be as up to date as what is shown in rounds. It would be helpful to pull from Essentris op-days (from op note) This information is not necessarily in WoundFlow… It would be really helpful for someone to look at it, and check if the orders are correct every day. Someone could check, yes, they've been checked and are ready to go. I think the diagram would be helpful [WoundFlow] – do they still have full thickness – do they have fungus – wound cultures? any pending cultures? Maybe we pull the wound cultures – could be in both places (also in ID).	Woundcare advanced practice nurse-6
1.8	[Patient View] Meds—It will also help, doctors give vanco multiple times, it will help to know which time it's being administered (e.g., third time vanco)	RN-2
1.8	[Patient View] Meds—Here, the heparin, we also give through vent and subcutaneously – give the route and it will help us avoid making an error.	RN-2
1.8	[Patient View] Labs: And then, pending labs – can we see that here – like for example, I have a patient that's bleeding, the Dr. orders labs every 4 hrs. times 4, and if it shows in the main screen, we will not miss it…It will be awesome if we have pending labs ahead of time – and abnormal results.	RN-2
1.8	[Patient View] So it's really great that there's trends. The only downside is there is no scale on these. So, for example, the Lactate graphic – there's no scale attached, so 4.07 doesn't tell me definitively where it is – I take it back – now that I see that [mouse over] that's good, I can see the numbers. It would be helpful to have numbers on either end, so at a quick glance I can get that information. I try to limit rounds on a patient to 10 minutes each, so I don't necessarily have time to mouse over to see the numbers. I'm having a hard time figuring out what this graphic represents [event history].	Resident-9
1.8	My bigger point is, I think we should tailor it, even though every individual needs to have input, I need, in reality, the attending is the key person for the day – so I think we need to tailor, focus things to making sure that those positions have the easiest view of what's going on. It's always the attending, and CN that need to have a good grasp of what's going on. If they don't know what's going on, you're going to have a catastrophic failure.	Unit administrator RN-5
1.8	For TBSA – it would be neat if we can pull this and see the entire picture.	RN-1
1.8	[WoundFlow] Oh, cool – so the color-coded image of the body that will be helpful. [RN suggesting that the color-coded image be provided]	RN-1

Wrong term/Misalignment

Date	*Data*	*Role/Page*
1.5	GU, do people call this GU? Am I the only person who calls it renal?	Attending
1.7	Should label it something everyone would understand – "Staffing Sheets," maybe.	RN-8
1.7	[Staff Manager] I would use our terminology – OIC – Super User, etc. That way you know who would use that tab.	RN-9
1.7	[Systems] Widgets seem like they should go in order they run from the report sheets. Should be consistent with that.	RN-10
1.7	Is therapy PT? Maybe there should also be PT. I guess we could put 'surgeon' – just because the surgeon could be someone different – and they are very involved with the care of the patient (Potential additions to Team Care Team Manager View).	RN-3

Means of Navigation/Inadequate cues/Awareness

Date	*Data*	*Role/Page*
1.5	Maybe we need to show whether the patient is on ECMO	Attending
1.5	I really think I should be able to double click on this [9:17] person and have something happen. But that's just me, I really want to double click, or right click. Right clicking and double clicking would be really useful. I like to right click on this and maybe go straight to the WoundFlow or something so I can see something about their burn size or maybe right click on this and go straight to their demographic screen, because that's demographic information. Or, right click and have more than one option, just coming out of all of this. It seems like I should be able right click on something, or left click on something, and it should do different things.	Attending
1.5	Okay, so that's kind of a nice feature that he can at least click on that and go to the patient overview on that particular patient, from that view.	Attending
1.5	I really like the 'back' option. I mean put this in web browser, you can't count the number of times… it's so much faster to go 'back' with a click here as opposed to Essentris where you have to go back up, find a drop down menu, and click something else. Same thing with EPIC, EPIC has no 'back' button.	Attending
1.5	Tube [13:50], I don't know what 'tube' means. Oh, that's because we're putting it in Endo and GI, instead of just Endo. That needs to be switched. [Although you had a good question because, "or is it NG Tube?"] I don't know…But these need to be split because these are not the same thing. [14:12]. GPM twice showing only if it's on; it's a pretty rare event.	Attending
1.5	What else can I start working on here [top left of Patient View with red arrow, purple and orange bands]? [15:12] Again, I think this should be consistent between all the different views, should be the same way of looking [between the Unit View showing these data and the Patient View]. So if I were to go back to the actual [15:22]… this view, you would think that it should look the same as this [15:24].	Attending
1.5	[Summary view] Then I'm trying to figure out how I would manipulate that period of time. So let's see if I can hit a month [16:18]. Can't hit a month. Three months? Can't hit any of those, none of those are functional… yet. I guess the only way to do this, with this. Now this, down here [16:30] makes me think I'm looking at 1, 2, 3, 4, 5 days maybe? That's hard for me to figure out because this only has three dates so I was initially thinking that this was three days' worth of data but it's not, this is actually before 31 December… 30, 31, and this is not the same as this [16:52], I think we've already identified that as an issue. And then I want to scale down here, there's no data so I don't know what I'm really looking at [17:00]. So I think if I'm trying to do… I'm coming into work today, what I'd want to see when I first walked in maybe the last 24 hours [17:11], probably the initial step, maybe, with the ability to check maybe… I don't know, through shift, which is 12 hours. So maybe through shift, that's probably a lot of information, 24 hours… so 12 hours, 24 hours, 72 hours, one week. And then, putting your own date range, or something like that [17:39]. "All"… that reset everything. It's interesting, year-to-date, ah… that's what that's doing [17:46], it's making it from the 1st of January because it's a new year. We don't think in terms of year to date in the ICU, maybe from admission to now would be useful. So it could be 12 hours, 24 hours, 72 hours, something like that, one week, and then the entire admission, those might be reasonable slices.	Attending
1.5	It would be a heck of a lot better to be able… instead of change element here [drop down button on right side of the green bar atop summary view, 19:22], for me to be able to right click on this [under cardiac, 19:24], I want to right click on heart rate [19:27], and change the value there. But it's here [19:33], so I guess that's some place to start with.	Attending

Date	*Data*	*Role/Page*
1.5	All right, where's that heart rate. I want to see heart rate. Heart rate 60 [19:43], and then upper limit. **Maria: Can you change it?** Make it 60. Well, this should make it do something, right? 60 and 60, that's the same value [19:54]. **[U] That must have been a typo.** Well I know but even if it is, let's make this 70. **So it'd be an alert of some sorts is what you're saying, perhaps? [20:00]** Wait a minute I want to see what happens when you change it. Because, theoretically, it's heart was 104, it didn't do anything yet. It changes to a minus. [?, 20:18]. All right, so theoretically, it did something here, I'm guessing, but I can't tell. As soon as I touch this [graph, 20:32], it gives you this little pop up which obscures my entire view of my trend, this has to go somewhere else, I can't see what that frame is. I'm assuming that it did something up here. This is annoying. [20:44]. There needs to be a time thing on this or a right click on it or something that makes this, "Ahh!"	Attending
1.5	[24:20]… Oh… that's a problem. Backspace takes you all the way out [24:25]. **[Josh] Yes, backspace in the web browser is the same as hitting the 'back' button.** Yeah, that's a problem. That will drive people…	Attending
1.5	Okay. Here's another thing that we've found in the past. If you're going to do this [run cursor over one graph] [28:37], it has to do it on all of them at the same time. Okay? And the reason for that is because what I'm trying to do right now is I'm trying to see if this guy's heart rate was up, why it was up. I'm trying to understand that.	Attending
1.5	Can I turn this off? [The text pop-up when placing cursor on graphs in central view [28:23]	Attending
1.5	The fact that there is more data off the screen that's a problem. I think we've already identified that as a problem before. If I didn't accidentally… if I wasn't a scroller, I might not have ever seen that because it's not terribly obvious that this is a scroll bar anyway. Maybe you need to have… if you MUST do that, you should probably have little arrows or something that highlight that there's information off the screen for a clinician. That would be intuitively obvious for them.	Attending
1.5	The Ventralizer [32:19], we made these things [putting the cursor of graphs in Patient View], the ability to turn them on and off. So I can go back and look at them on and off, and see relationships. That's another way of taking care of real estate so if I want to look at this one, great.	Attending
1.5	[JP Video 2, 12:29] that's kind of cool, I just discovered that Task and Co-morbidities change colors when I hover over them, but they don't do anything when I click on them. **[RN-admin] So it's just an undeveloped feature?** **[Josh or Tony] Yeah.** It's cool though.	Attending
1.5	Eventually having the co-morbidities here would be super cool though because these co-morbidities constantly affect how these patients heal, or don't heal, and to be able to quickly know and I'm new on this patient, I've never had this patient before, what's the patient's past medical and surgical history? To be able to click on that and have that listed would be cool.	Attending
1.5	There's also added here now, a Rehab and Wound Care section but I see a lot of stuff down here [JP Video 2, 15:00] so why couldn't those be tabs? Why couldn't we go all the	Attending

Date	*Data*	*Role/Page*
	way around maybe? Go all the way around the corner, that'd be kind of neat, maybe.	
1.5	We know what some of the important things are to capture and maybe we need to put separate tags along these lines [on the timeline in Patient View, top of central screen]. Line changes, any procedures, anything that goes up in the Team View—procedures, dressing changes, ORs, intubations, extubations, those are procedures. Bronchs don't always come up that much, I mean even when we do them, they're procedures, and they aren't captured on the Boards at all. Intubations and extubations get captured on that board. Big dressing changes, the first post op dressing change. Wound back down gets captured. Line changes are captured. ORs obviously are captured… Code would be captured. I haven't had one since we've had team meetings [unintelligible, 4:35]. All right, I haven't looked at this yet, by the way, in this view, I'm not sure what to do with it. But I'm going to look at wound care [JP Video 2, 4:48].	Attending
1.5	[RE: how frequently CCS pulls from Essentris and how CCS data is refreshed, JP Video 2, 7:22] will be okay. You might put a little "refresh" button on there and people will remember that. So what I'm looking at this medication thing [JP Video 2, 7:30] it's not helpful. And the reason for it is because there's no consistency with the way the information is displayed. I don't know what the right answer is here but the information needs to be displayed in a consistent fashion. If the intent of this is just to show the medications they are on, then get rid of everything else. All that information should go away. If the intent is to show drug and dose, great, it should be drug-dose. if the information is drug-dose-timing, like every 'x' number of hours, then it should be drug-dose-time. And I think the reason for that might be is we're pulling from the medications list as opposed to pulling from the order section. So, it would probably be better to pull this list from the Orders section for meds because the Orders section has those things pulled out in a more consistent fashion. And then maybe what you do is what's important? My assumption is that if the order is written, they're getting the drug. That's my assumption, right? So, maybe what we'd do then is the check on it, is look into the chart and if it wasn't given, if this med was… if it's a brand new med, you might have to do a rule, the rule might be, "Order just acknowledged," right? There's an acknowledgement time? If the acknowledgement time is less than… I don't know… one hour ago, don't look for held meds, or don't look for doses. Right? Don't look for med being given. However, if the acknowledgement is older than that, look and see if drug has been given at the appropriate time. And it might be even more… probably even more important than that, if it's a once a day drug, and it was written today, you probably don't look back more than 24 hours. Right? To see if it was given or not. If it's an every six-hour drug, you'd have to look back six hours ago, and if it hasn't been given within the last six hours, you might spend another seven hours, and then it would say, "not given yet," and make it red. [JP Video 2, 9:35]. Right? Or if it has "held" in there like this [JP Video 2, 9:38], then you might make it yellow, or something like that. There's a rule related to the order frequency with which it's being given. And then, all of a sudden, this becomes meaningful, right? Because now I'm looking at the current medication list, it's not just the medications that were given in the last 24 hours, and when they were given. The current medication list, and then I'd know whether it was missed or held, just by looking at it—red or yellow. I think my assumption is that it's given. I'm not sure if that's… you'd want to do if it's an exception to the rule. The rule is that it's given… So maybe what you do is you can hover over it and get more information about it.	Attending
1.5	**[RN-Admin] Like pain medicine, that might be a better example. When was the last time the patient got morphine?** If it's a PRN end drug. So if you hit "PRN" maybe the rule for that is different. You look at the PRN drug and you say, "When was the last PRN drug given?" It'll show you something.	Attending

Date	*Data*	*Role/Page*
1.5	**[RN-admin] It's just somewhere there are some PRNs?** **[Josh] Yes, if you look at the second one from the bottom there [10:50], like all that three lines of blue text, that's straight from that one field in the database.** And that's okay, I think, because it's going to come the same way out of their order. It's going to look just like that. What I'd do is, again, I think we need to make it cleaner, this is too messy to look at. So this might be the medication list [JP Video 2, 11:12]. Again, you might have a green, red, or yellow, if you want to prevent information at this level. But then maybe you hover over it, or you left-click on it, and it shows it. That may be another way of doing this, if we separate out left-click and right-click. Maybe left-click turns this box on, left-click turns it off. If I want to get some more information about it, I can right-click and do something with it. I kind of like that idea, left click turns it on/off, makes it go away. [JP Video 2, 11:42] What's that value? Click. Oh, that's what that value is. Click, I don't need that any more. That'd be great. And same thing over here [JP Video 2, 11:49], you might be able to left click it, it pulls up more information about it, left click, it turns off.	Attending
1.5	RE: Tasks and co-morbidities: I hover over them, I left click on it. You say, "Okay, here are the tasks that are due." Right? Or, maybe just simple right here, "Incomplete task." That's the rule here. Right click on it, open up Tasks, you go to Tasks, and it shows you the whole task listing. So it's a lot easier to get to it	Attending
1.5	[Salient to machine learning] Right, just incomplete tasks. Very simple list, something like that. And that gets back also into our conversations about this ability to build knowledge about what clinicians are interacting with. So if the first thing they do is they always go to the task list, I click on this and I want to see what the tasks are that are due, maybe that's the first window we should start pulling up for people. Right? If the first thing that they do is hover over the medications, and the only one they ever hover over is norepinephrine, well maybe we need to pull the norepinephrine information into this box, somehow, someday, because they always look at that. I mean every time norepinephrine is there, they always click on it, 100% of the time. That would be meaningful information for us to capture. So we get this constant linking, clicking, and those kinds of things, again, I think that's useful [JP Video 2, 14:52].	Attending
1.5	**[Opportunity to mis-click patient in drop down list—and not notice you are looking at data for wrong patient]** Click on the patient, yes. Double click. Then it will automatically bring in a patient, this is the home screen. I think that I'm on Patient 12, I meant to click Patient 12, but I'm on Patient 13, I don't notice here because that's not terribly obvious. And I start interacting with Patient 12 except I'm really interacting with Patient 13. [JP Video 2, 17:03]. You might be less likely to do that because there's more contextual information here, there's both spatial information and there's a better, clearer widget here for them to interact with [JP Video 2, 17:13], and I still want to double click that.	Attending

Date	*Data*	*Role/Page*
1.5	We're letting people add their own checklist items? **[Josh or Tony] This is something we could link to the role-based system but right now it's not.** I think we've seen a good display of what the Checklist tool should mostly look like. [JP Video 2, 19:59] I guess I have to go to entry in order to put in something here. **[Josh or Tony] You can add.** I feel like there should be a box here for me to start typing in. I can't put anything in these things, you have to do an "add" first [JP Video 2, 20:15]. That's too many clicks in my mind to get to this point. People say, "I don't really want to do something." This is a test… [inserting into box]. [JP Video 2, 20:32]. I can't add my own person. So what happens if a person who is on this is not somebody who is not on the list. Do you have to be in the list? **This once again goes back to the whole CAC authentication, if there's CAC thing, it's going to have everyone with a CAC card.** So there are tasks that are not specific to any individual person and I will tell you that the team right now does not think about assigning any task to any person, totally foreign concept, they don't do it at all. There's no assignment. Right Chris, by and large? Rarely, comes up now and then, "Are you going to do that?" "Yes." "Okay." That's how tasks assignment goes. They're assumed… I don't know what to do with this, assigned and categories as well. My anxiety is if we have an assignment here, right… I don't know that people will know what to do with it yet. [JP Video 2, 24:08]. I mean even if they say, "Well, who is it assigned to?" I don't know… so that's a part of the research question, I suppose. **[Admin-RN] Yes, would it be better, for starters, just to put the roles there [JP Video 2, 24:26].** Or put both. I mean let somebody assign it to a person, or a role. I don't know. The category thing, also, I don't know what to do with. I also found out that I can just get rid of my tasks without ever saving it by accident. [JP Video 2, 24:47] I accidentally closed it, right, so… can I 'Ctrl-Z' it, no I can't 'Ctrl-Z' it. **[?] Does the save feature work?** Yes. So I went along here and I hit this back [unintelligible, JP Video 2, 25:05], so I don't know why I would have this button AND a clear button since they do the same thing, apparently. I want to be able to edit it [text].	Attending
1.5	Pause… what does 'Pause' mean? So we had … it's … oh… try to make it come back [25:53]. **It's deleted.** I want it to come back. I was testing it. **All right, three confirmed delete dialogues.**	Attending
1.5	The scheduling view now. I keep trying to…. Whoa, why'd that go away [JP Video 2, 34:30]? Well, it automatically creates a new thing as soon as I left click anywhere. That's kind of interesting, I can make lots of things. Oh it doesn't, it moves it.	Attending
1.5	I was thinking it would be really nice to copy this task and put it somewhere else, which I can't really do.	Attending

Date	*Data*	*Role/Page*
1.5	The blue one [task on schedule] is covering it up so you can't even see the orange one [JP Video 3, 0:07]. I don't care, I just moved it. I didn't want to edit it, that's it, it was driving me crazy. Every time you touch it, if it's just a move, it opens up another screen. Got it. [JP Video 3, 0:22]. Okay, it seems like also the same color may not want to overlap the same thing because I didn't change that color, that was blue before, it changed to green. Anyway, it seems like, theoretically, these people will be doing the same… it'll be the same person doing this and this, and you probably can't be in two places at once, I would think. Again, I think the idea of being somehow or another to copy it, to copy and paste it somewhere else so you can build, or whatever you want to do, would be kind of nice.	Attending
1.5	What I was thinking when I hit this messaging channel [JP Video 3, 2:10] was it would just take me to the messaging channel and I would do something else. But I have to actually hit "messaging channel" and then a new patient. A two-step process for something… I don't know… it seems like it should be directed to a generic messaging window and then you could pick the patient. I don't know. What happens here [JP Video 3, 3:19] is it seems like this gets really long, and if I look at this, I can interact with this faster because I don't lose my place. Right? Any time you go back to this, if it's this, then if I'm looking for messaging then I have to go find it again. And that' s my take on it [JP Video 3, 3:40]. **But aren't you already in messaging?** … so if you're in messaging right now, right? [JP Video 3, 3:50], and if I open this again, the first thing I'm going to see is the messaging thing is going to be expanded. Right? But I don't want to do messaging, I want to do CRN deal. Right? So, now I'm thinking about clicking this [JP Video 3, 4:00], but then I have to click it and then I have to go find my patient again. It seems like I would somehow or another click this and I would go to a rounds CRN view, and then I'd pick the patient that I wanted somehow. It should always come up like this maybe first, maybe that would be more palatable because then I can just get used to where I'm going to look, click it, find it, as opposed to it is expanded to when I first get to it. That just seems like it's not as…	Attending
1.6	Essentris can't scroll down on a medication – have to move mouse over to the bar and slide it. If we had a better view of that, that would be useful.	CRN-2
1.6	If I could waive my mouse over, and show vital signs graph, that would be helpful.	CRN-1
1.7	Arrow on side menu needs to shift orientation so that I can see that it needs to go back up. When it expands, the arrow needs to rotate, so I know that it needs to be retracted.	RN-2
1.8	Maybe something on there, like repeat orders – back in the day we would do a 12-hr. chart check. [to remove redundant orders]	LVN Wound Care Group Session-8
1.8	What happens if something is completed on the task list, does it vanish? Would prefer that there is a box that you can check off.	LVN Wound Care Group Session-8
1.8	[Patient View] Yes, customize by patient [response to J asking if he was suggesting that provider customization of screen is desirable] – So does this show all of the labs? Critical or abnormals – results – is this visible? If it's one click away, that is easier. Doctor comes in and wants to see the results, so that would be helpful. Event History – it's not clickable right now? That would be good.	RN-1
1.8	Medication – if it's due – 11a.m. if there is medicine due – if it could line up there. …the last hospital I worked at had Meditech – it would show medications due in the next hour.	RN-2

Date	*Data*	*Role/Page*
1.8	Meds—So probably the other thing with this one is how often we're going to give the medication. As a nurse, that will give us an idea of how to use our time…so for instance we give a medication every 4 hours, so if the system tells us it's due in 4 hours that would help.	RN-2
1.8	[Patient View] Meds—It will also help, doctors give vanco multiple times, it will help to know which time it's being administered (e.g., third time vanco)	RN-2
1.8	Okay, so this is from 5 Jan., [ID widget] that would be very valuable. I'm assuming we have to determine how long we're going to keep this data? A week, a month? Melvin: If you're pulling all that data, and a patient has been on unit 95 days, that's a lot of data. Melvin: I might not want to see all 90 days [for everything], but if it's an ID issue, I might need to see all 90 days. Jimmy: If we're pulling from Essentris, does it keep it, or does it dump that once I change dates? Because theoretically you could have some data change from 2 days ago, and it affected data, I'm assuming it would update from Essentris?	RN unit admin and RN leadership-6
1.8	[Patient View] So it's really great that there's trends. The only downside is there is no scale on these. So, for example, the Lactate graphic – there's no scale attached, so 4.07 doesn't tell me definitively where it is – I take it back – now that I see that [mouse over] that's good, I can see the numbers. It would be helpful to have numbers on either end, so at a quick glance I can get that information. I try to limit rounds on a patient to 10 minutes each, so I don't necessarily have time to mouse over to see the numbers. I'm having a hard time figuring out what this graphic represents [event history].	Resident-9

Miscellaneous

Date	*Data*	*Role/Page*
1.8	Maybe something on there, like repeat orders – back in the day we would do a 12-hr. chart check. [to remove redundant orders]	LVN Wound Care Group Session-8
1.8	Tasks are good if we can figure out who will be loading those – is it multidisciplinary during rounds?	LVN Wound Care Group Session-7
1.8	My biggest concern is that this will reduce [human-human] communication, like the 'Team View' board outside of the room. The Team View checklist outside the patients room is reducing the conversations on rounds. [sense: loss of sensemaking, loss of nuance that is present in verbal exchange regarding patients stats/condition, or with regard to family needs.	RN-audio only
1.8	The verbal communication with doctors on rounds is how trust is established—the physician learns if they trust your perceptions. Rounds is the only way they know if I know what I am talking about. If they trust my spidy-senses they will respond to me.	RN-audio only
1.8	I won't use this—I already know it because I enter it in Essentris and I can't change it here. Might be useful if I was monitoring someone else's patient. If screens were dynamic and I could see and [interact] with them in one spot, it would be useful. If I could enter data. Maybe useful for nurse to nurse handoff to have this display because I'd have to flip through screens on Essentris. A screen that shows similarity between patients from the past would be helpful.	RN-audio only
1.8	So like if you put something here and then on another screen – it's redundant. Also, with this one – norepinephrine – If I give 5ml/hr., when I click that I give it, will the dose that I give go automatically to the Is and Os? In Meditech, [the system] that I used before, once I start the med., and input the does, the I/O will auto populate every hour unless I change it. That's right. But here, we're giving the same med. every hour, but we need to put it in continuously, and if we're interrupted, it's easy to forget to do that.	RN-2
1.8	Melvin: The other thing is that we are looking into Vocera – that will dramatically change the way communication takes place. There is a lot of functionality within that system.	Nurse leader-6

Appendix F. Trip report: USAISR User Interface Data Collection 04-09 January 2015

16 February 2015

From: Christopher Nemeth, PhD
To: Mr. Tony Story, CDMRP
Cc: Jose Salinas, PhD, Army Institute for Surgical Research

Subj: Trip report: USAISR User Interface Data Collection 04-09 January 2015

1. Executive Summary. Applied Research Associates, Inc. (ARA) is under contract W81XWH-12-C-0126 to the U.S. Army Medical Research & Material Command's (USAMRMC) Telemedicine & Advanced Technology Research Center (TATRC). The Cooperative Communication System is intended to be part of a joint cognitive system that allows the healthcare team to remain connected to an individual patient and to each other across time and space as the team delivers patient care. In addition to the improved communication among providers, this project explores the potential to provide relevant information to support clinician decision making. Evaluation visits leverage the foundation data collection and analyses provided by determining how well prototype versions of the graphical user interface (GUI) support individual and team cognitive work.

2. ARA Staff. Research personnel on this trip included Christopher Nemeth, PhD, Jeffrey Brown, Megan Beck, Josh Blomberg, and Tony Hamilton from CSD and SED. Greg Rule and Dianne Hancock from ARA's San Antonio office provided local coordination support.

3. Activities. All information was collected in accordance with IRB-prescribed procedures. The trip had been planned to conduct an initial usability assessment of the Module One software prototype. The assessment would follow task scenarios, collecting quantitative data (e.g., time to complete task) and qualitative data (e.g., subjective report on ease of use). Findings would be used to improve layout, terminology, and navigation. A week before the visit, the USAISR staff asked that the visit agenda be changed from a usability assessment to a series of informal reviews by members of the clinical staff.

a. Design informal review sessions. During the week of January 5-9, 2015, the CCS team visited USAISR, San Antonio and 26 individuals provided informal review of the CCS prototype.

- 10 RNs of which 4 were charge nurses, 2 worked in administrative roles and 4 work as bedside nurses
- 1 attending physician
- 1 resident physician
- 8 wound care team members
- 6 rehabilitation technicians

The ARA team also met with the USAISR staff members who regularly discuss decision support software to review the GUI, patient condition related data, navigation, and other features.

b. USAISR Update Meetings. The ARA team (including Josh Blomberg), LTC Pamplin, and representatives from SSCI discussed the site visit, Phase II prototype development, timeline, and issues related to database access.

4. Results. Given USAISR's change in goals for the data collection trip, we did not have a research design to structure or tabulate the sessions. With no means to derive findings that would indicate observation strength, the ARA team sought results that could be used to improve the software prototype. Through multiple passes and an in-person review session, the ARA team developed ten categories of feedback for improvement using thematic analysis. In contrast to rigorously vetted data from Year One, the January visit comments are individual opinions. Some corrections are helpful, such as the medications listing in the Patient View. Many of the remaining comments indicate personal preferences and speculations about the CCS. The usability assessment that had originally been scheduled for January is planned for October 2015, when Module Two is completed.

a. Interface design feedback session notes. The team has transcribed and categorized in-depth notes accounting for data that were collected during reviews provided by clinicians.

5. Further work. Next steps for the project are:

a. Apply results from this data collection visit to refine the interface screen concepts, navigation, and layout.

6. For further information, contact Dr. Nemeth at 937-825-0707, or cnemeth@ara.com.

Appendix G. Evaluation Protocol CCS User Interface Prototype

Evaluation Protocol
CCS User Interface Prototype
January 2015

I. Introduction and Orientation *(5-7 minutes)*

[Introduce self]

Thank you for your time and willingness to participate in this session. Our research team has been working for the past couple years to develop a tool that will assist you and the rest of the BICU team in caring for your patients. We have interviewed and observed the clinical team to understand the work context here in the BICU, and the challenges and needs related to communicating, coordinating, and accessing information. Based on our analysis, we have developed an initial version of an interface that is intended to help you find and use the information that you need in order to do your work.

We are here at SAMMC this week to learn from members of the clinical team about how the prototype works and what needs to be improved. We want to ensure this system is set up in a way that is easy to use, understand, and navigate, and that you can find the information that you need to do your work. The system is not far enough along to use it for decision making in the context of realistic clinical scenarios. Instead, we want to assess the overall look and feel, and learn whether this early prototype is easy or difficult to navigate. Upon completion of the session we are interested in hearing your thoughts and suggestions for ways the prototype can be improved to better meet your needs as a member of the BICU team.

Overview of Session

The way this session will unfold is:

1) We will begin by asking you a few things about your background.

2) We will then show you the prototype user interface so you can get an overview and orient yourself.

3) When you're ready, we will describe a situation that could occur on the BICU, and ask you to use the interface to locate information relevant to that situation. We are interested in understanding how well the interface helps you find what you are looking for. Please take whatever time you need, and feel free to click through the interface in whatever order makes sense to you. When you're finished, we'll move on to a second situation, and a different set of information we'd like you to locate.

   If it works for you, it's helpful for us if you can think out loud while you are working with the interface. Let us know what you're looking for, trying to do, or having trouble with.

4) After that, we have a few questions we'd like to ask about your experience using the prototype – i.e., what works well, what doesn't, and any suggestions you have for improving the interface design.

The point is to figure out what about the interface works well and not so well. Watching you use the interface to find information is going to help us identify problems and improve the interface so it better meets your needs. We really appreciate your participation. You can stop at any time if you want to.

Consent

[Confirm consent to video record.]

Do you have any questions before we begin?

II. Background *(2 minutes)*

We'd like to start by gathering some information about your background.

[Facilitator will write responses on a formatted sheet of paper.]

- What is your profession? (e.g., RT, nurse, etc.)
- How long have you been in this profession?
- What is your clinical role on the BICU?
- How long have you been working on the BICU?
- Note participant gender
- On a scale of 1-5, how would you rate your comfort with information technology, with 1 being not comfortable with IT and 5 being very comfortable?

1	2	3	4	5
not comfortable				very comfortable

III. Prototype Interface Exploration *(3-5 minutes).*

Here is the current prototype user interface. There are multiple views – e.g., Unit View, Patient View, Rounds CRN View. Please take a few minutes to become familiar with these views; explore them and see what information is offered.

We're still in early stages of development. So there is some data that has not been programmed into it. In those instances, you'll see a placeholder for that information and the phrase: data unavailable.

If you're comfortable with it, it'll help us if you think out load as you go through this. We're interested in hearing about anything you see that's noteworthy, interesting, or problematic. Also, feel free to ask any questions you might have.

V. Scenario Completion *(20 minutes)*

[Below are several potential scenarios. The intent is to use two of the scenarios within the actual evaluation (possibly a third if there is time available).]

What we would like to do now is describe a situation, and ask you to use the system to locate or share information relevant to that situation. We're going to give you a description of those tasks, so don't worry about remembering all of them.

As you work through the situation, see if you can picture yourself using the system during your regular clinical work. Please think out loud as you do this. That helps us understand better what you are thinking about and doing. If you get stuck, or can't figure out how to get the system to do something, feel free to make your best guess of what to do. [As participant performs scenario tasks, facilitator and note-taker will be taking notes of where participant seems stuck. Won't let them struggle too long – e.g., no more than 30 seconds]

Any questions before we start?

Scenario 1: [Unit View & Messaging] (any member of team)

You have just come on shift on the BICU after being off the unit for the last two days. You want to get an overview of what is happening on the unit. You are interested in getting a general sense of patient acuity on the unit, which patients are currently most unstable and which seems to be doing well.

Here is the list of what we'd like you to use the system to do. Please work through these in any order that makes sense to you. [Provide participants with a list on paper]

- Log into CCS (using provided username and password)
- Determine Patient 3's original TBSA and current percent open.
- Identify which patient(s) on unit is (are) currently the "sickest" and/or least stable.
- Determine which patient(s) you are assigned to
- Identify who the ICU attending is this week, and which resident is assigned to your patient.
- Identify any concerns raised by other staff members in the messaging.
- Send a message to the wound care team lead asking what time they want to do wound care. (This assumes the scheduling widget does not have wound care scheduled for this patient.)

(Facilitator/notetaker will note: Elapsed time, number of steps it takes the user to perform the task, tasks they were able to complete, difficulties they encountered)

Scenario 2: [Patient View and other] (all team members)

It is 0600. In preparation for morning rounds you need to gather information about your patient's status. You use the CCS system to begin gathering information about Patient 5.

- Access the Patient View for Patient 5
- Change time window to see past 24 hours of patient data
- Identify the information that matters to you in preparation for rounds for patient 5.
- Tell us what's important to you in your clinical role and what you're finding.

Scenario 3: [Patient View] (Resident and attending physician)

As you are gathering information from the patient record, the bedside nurse mentions to you that he's concerned the patient is showing early signs of sepsis. The nurse's comment prompts you to look at more detailed information about the patient's status.

- Review detailed information on the patient's vital signs. Specifically, review HR, BP (MAP/SBP/Pulse Pressure), CO & SVR if available, WBC, Temp, Blood glucose/Insulin requirements over past 24 hours, gastric residuals, UOP, BUN/CR, Lactate and/or ScvO2/SvO2, Mental status changes, platelet count, Ins/Outs, CXR, cultures performed.
- Determine if the patient has required vasopresssors and/or fluid boluses over the last 8 hours.
- Determine if the patient is on antibiotics. If so, determine which ones and what dose.
- What other data are a concern for you?

Scenario 4: [Care Team Manager] (charge nurse, OT/RT lead, lead wound care, chief resident)

It is 1330 and you have been notified that a patient with severe chemical burns on his face, neck, and hands is being transported to SAMMC. PAD created the patient's record. As the new patient is admitted to the BICU, you need to assign the nurses to care for the patient and determine who will be the attending physician assigned to the patient.

- Identify available nurses on the unit during this shift.
- Change team member (RN, OT/RT, wound care) assigned to Patient 6
- Assign your team member role (RN, OT/RT, wound care) to Patient 4.
- Determine which attending and resident is assigned to Patient 6

Scenario 5: [Patient View] (bedside nurse, charge nurse, attending, resident)

Your patient is unstable and may not survive the initial 48 hours post burn. You, the surgeon, and the resident are discussing whether to pursue more aggressive treatment or whether to move the patient to palliative care. To make the decision, you need to review the patients' data together and understand how the patient has been trending over the last 24 hours.

- Access the Patient View for Patient 8
- Change time window to see past 24 hours of patient data
- For Patient 8, including vital signs (including HR, BP (MAP/SBP/DBP, SpO2, pH, Lactate, UOP, Abdominal Pressure, Ventilator Settings P:F ratio or OI, vasopressor requirement, renal function, neurologic function – pupils, GCS)over last 24 hours,
- Change time window to see past 48 hours of patient data, and identify whether there are any indicators of early burn wound infection causing sepsis.
- After looking at trends, post a message on the patient's message channel indicating the attending has decided the team will need to meet with the family to discuss palliative care.

Scenario 6: [Rounds CRN view - entry] (charge nurse only)
You are the charge nurse and are in the midst of morning rounds. You are currently rounding on the patient in Room 5. As the team discusses the patient, you are capturing aspects of what is discussed. So far, the team has discussed what labs should be discontinued for the patient, which medications can be renewed and which should be discontinued, as well as removal of the patient's central line [can add others here that make sense].

- Verify that you are viewing the checklist for patient in Room 5.
- Verify whether there are any tasks previously assigned for the patient that have not yet been completed.
- Identify the patient's current medications.
- Add a change to the dose of propranolol or Lasix.
- Repeat/extend rehab order from yesterday
- Make a change/edit to goal for rehabilitation today (was TLC now should be Tilt). Alternatively, dressing down on Saturday change to Monday.
- Submit final set of tasks.

Scenario 7: [Unit schedule]
[will need to add tasks once we see prototype and functionality]

V. Post-scenario Questions *(5-10 minutes)*
We'd like to ask you about your experience using the interface.
Please choose the number that best reflects your response, and let us know why you chose that.

- The interface helped me to perform the tasks in these scenarios. [5pt Likert scale]
- I could find the information I needed. [5pt Likert scale]
  Could you give us an example?
- Were there any aspects of the interface you found particularly useful?
  If yes, which ones, and how were they useful?
- Were there aspects you found difficult to use?
  If yes, which ones, and what made them difficult?
- Do you have suggestions for how the interface could be improved?
- Would a system like this be easily adopted (or integrated into current workflow)? If so why? If not, why not?
- Are there any additional comments you'd like to share we haven't discussed so far?

VI. Conclusion (*1 minute).* Thank them for their time and dismiss participant.

Appendix H. CCS Requirements Validation Survey Memo

Interviews with Burn Intensive Care Unit (BICU) personnel revealed several core requirements for an information technology solution to support clinicians' cognitive work and synchronization in the BICU. These interviews also revealed several key challenges and barriers to safe and effective care on the BICU, from which we created a set of problem statements and system requirements to address each problem. To validate the problem statements, 25 BICU personnel completed a survey in which they rated their level of agreement with the challenges encompassed in the problem statements. Respondents rated challenge statements on a 5-point scale (1 = Strongly Disagree to 5 = Strongly Agree). They provided additional comments regarding the challenges in an open narrative following their ratings (see Appendix D1). Similarly, respondents rated the recommended system requirements on a scale of 1 = Not Important to 5 = Extremely Important, and commented on recommended requirements in open narrative following the ratings (see Appendix D1). This memo presents the findings from this survey as they relate to each problem statement and system requirement.

Table 1 presents respondent demographics as well as data pertaining to the question: "Have you ever had difficulty finding information on the BICU?"

Table 1. Respondent Demographics

Role	Mean BICU Experience (years)	Mean Healthcare Experience (years)	Percentage of Respondents who Reported Difficulty Finding Information
Nurse (n =12)	6	19	83%
Therapist (n = 5)	2.9	13.5	25% [a]
Physician (n = 4)	1	6.5	67% [a]
Other (n = 4)	5.5	12	67% [a]
Total (n = 25)	4.5	15	68%

Note: The "other" role comprised one registered dietician, one wound care specialist, one ICU technician, and one manager.
[a] Each of these groups is missing response data from one respondent; thus, these percentages are based on n – 1 responses.

Respondents who reported experiencing difficulty finding information indicated that the difficulty often resulted from software accessibility issues, for example, being blocked by firewalls, a lack of access to programs and information systems, and an absence of software on some computers. Some respondents also reported that even after accessing sources, information appeared to be missing. For example, the computerized documentation system, Essentris, contained incomplete documents, and other sources lacked information on policies and practices. Respondents also reported general inefficiencies in obtaining lab results and information from other services not collocated in the BICU.

To find missing information, respondents attempted to locate other staff members who could find the information or assist in finding the information. However, respondents reported that it was often difficult to find the required staff members, such as POCs and physicians, in a timely fashion. Respondents indicated that when these difficulties persisted, they notified people who could rectify the problem, or they attempted to address the problem, for instance by increasing regular interaction with critical staff members. Note, however, that although two-thirds of respondents reported ever having difficulty finding information, they neither agreed nor disagreed that this difficulty occurred often (M = 3.00; see Table 2).

Table 2. Survey Data Pertaining to Difficulty Finding Information

Challenges Question	Mean Response (SD)	Response Category	Group Difference
It is often difficult to find the information we need to do our work.	3.00 (1.27)	Neither Agree nor Disagree	No

The following results comprise survey data pertaining to each of ten specific work problems and requirements to be addressed by the Cooperative Communication System (CCS).

Problem 1: There is no effective means to synchronize and adapt different aspects of patient care over the course of a shift, across the caregiver team.

Requirement: The system shall provide access to a plan of patient care, visible to all caregivers responsible for that patient that includes:

- Current patient status and top-level assessment; Goals and priorities for those goals; Changes/updates (e.g., indicating that plan is being updated when one caregiver is working on it); Schedule of activities and any changes, timeline; Orders and their status; Identity and contact information for patient's care team.

Validation Summary: Respondents tended to agree that they need an effective means to synchronize aspects of patient care and adjust the care plan. They rated the potential CCS features that would address these challenges as important or extremely important (see Table 3).

Table 3. Survey Data Pertaining to Problem 1

Challenges Question	**Mean Response (SD)**	**Response Category**	**Group Difference**
We need an effective means to synchronize different aspects of patient care and adjust the care plan (e.g., wound care, rehab, line changes, etc.) over the course of a shift and across the caregiver team.	4.54 (0.78)	Agree – Strongly Agree	No
Potential Features Question			
List of goals that are prioritized.	4.44 (0.71)	Important – Extremely Important	No
Changes and/or updates to patient care plan.	4.24 (0.93)	Important	No
Schedule of activities and any changes.	4.20 (0.76)	Important	No
List of orders and their status.	4.16 (0.85)	Important	No
Access patient care plan.	4.08 (1.02)	Important	No
Current overview of patient status[a]	4.00 (0.91)	Important	No
Name & contact information for patient's care team.	3.84 (0.85)	Important	No

Problem 2: Lab cultures are processed but requestors are not made aware that results are in, resulting in delay of treatment and other issues.

Requirement: When any tests are ordered (lab, x-ray, etc.), the system shall push results notification to requesters and caregivers for that patient.

Validation Summary: Overall, respondents agreed that they often do not know when a patient's culture results are completed or updated. However, level of agreement differed by role: Physicians and therapists were less likely to agree with this statement than were nurses and 'others.' These groups all reported that a feature to push test results to requesters and the patient's care team would be important (see Table 4).

Table 4. Survey Data Pertaining to Problem 2

Challenges Question	Mean Response (SD)	Response Category	Group Difference
We often don't know when a patient's culture results are completed/updated.[a]	4.00 (1.08)	Agree	Physicians = Neither Agree nor Disagree
			Therapists = Neither Agree nor Disagree—Agree
			Other = Agree
			Nurses = Strongly Agree
Potential Features Question			
Pushes results of tests (labs, x-rays, etc.) to requesters & care team for that patient.	3.96 (1.06)	Important	No

[a] Group differences: $F(3, 24) = 6.41$, $p = .003$

Problem 3: There is pervasive confusion around orders, to include whether they have been placed/entered and when and what their status is (in process, complete), whether a new order is redundant with an existing one, whether an order has been updated/changed, and lack of access from team members to existing orders/status.

Requirements:

- The system shall enable multiple team members to view, update, track, and process orders from a simple (possibly handheld) application, available on numerous devices, indicating changes/updates and current status of each order.
- Once an order is in process, the system shall provide team members who act on it with a simple, accessible means for annotating their action in the system; the system shall update immediately and push notifications to subscribers
- The system shall enable team members to subscribe to push notifications for certain patients about status of in-process orders/labs/procedures.

Validation Summary: Respondents neither agreed nor disagreed that they are often uncertain about a patient's order status (whether placed, entered, changed, in process, completed, etc.). However, they reported that including CCS features that address this potential uncertainty would be important to their work (see Table 5).

Table 5. Survey Data Pertaining to Problem 3

Challenges Question	Mean Response (SD)	Response Category	Group Difference
We are often uncertain about whether orders have been placed/entered and whether an order is in process or is complete.	3.21 (1.18)	Neither Agree nor Disagree	No
We often do not know when an order has been updated or changed.	3.04 (1.27)	Neither Agree nor Disagree	No

Table 5. Survey Data Pertaining to Problem 3 (continued)

Potential Features Question			
Simple, accessible way to annotate any updates or changes to orders.	4.24 (1.01)	Important	No
Push notifications/updates to care team when a change to an order is made.	4.13 (0.90)	Important	No
Accessible on numerous devices (e.g., bedside computer, laptop/portable computer, portable device like a cell phone or tablet).	4.04 (0.94)	Important	No
Ability to view, update, track, & process orders.	3.88 (1.05)	Important	No
Subscribe to push notifications for a patient about status of orders/labs/procedures.	3.72 (0.98)	Important	No

Problem 4: IT issues and work process requirements frequently require redundant and/or repeated information capture and data entry, resulting in the documentation process being highly inefficient and time consuming.

Requirements:

- The system shall enable team members to push data to multiple systems through one data entry process.
- The system shall only require team member to document information in one common location; information elements then populate other redundant data entry systems as needed.

Validation Summary: Respondents agreed that redundancies exist when entering patient data across different systems. They tended to agree or strongly agree that care documentation infringes upon time potentially spent with patients. Respondents indicated that the ability to document information in one system that subsequently shares that information with other systems is important or extremely important (see Table 6).

Table 6. Survey Data Pertaining to Problem 4

Challenges Question	**Mean Response (SD)**	**Response Category**	**Group Difference**
We often have to capture and/or enter the same patient multiple times in different systems.	4.04 (1.04)	Agree	No
Care documentation reduces or compromises time we could spend with the patient.	4.39 (0.72)	Agree – Strongly Agree	No
Potential Features Question			
Ability to document information in one common location; information elements then populate other data entry systems as needed.	4.64 (0.57)	Important – Extremely Important	No

Problem 5: Lags in the system produces information that can be stale or inaccurate, causing lack of situational awareness (SA) of highly unstable patients.

Requirements:

- The system shall enable team members to designate patients as unstable/high risk.
- For those unstable patients, the system shall enable real-time dissemination (i.e., text message) of updates to status, orders, or requests to all team members on handheld/portable devices.

Validation Summary: Overall, respondents agreed that inaccurate or stale information could lead to poor situational awareness of highly unstable patients. However, physicians were less likely than all other respondents to agree with

this statement. All respondents rated as important a CCS feature that allows them to designate patients as unstable or high risk. Also important is that the system enables real-time dissemination of care information for these patients(see Table 7).

Table 7. Survey Data Pertaining to Problem 5

Challenges Question	**Mean Response (SD)**	**Response Category**	**Group Difference**
Inaccurate or stale patient information makes it difficult to maintain good awareness of highly unstable patients across the team.[a]	3.82 (1.00)	Agree	Physicians = Disagree—Neither Agree nor Disagree
			Nurses/Other = Agree
			Therapists = Agree—Strongly Agree
Potential Features Question			
Designate patients as unstable/high risk.	3.92 (1.00)	Important	No
Enables real-time dissemination (i.e., text message) of updates to status, orders, or requests when a patient is unstable.	3.96 (1.21)	Important	No

[a] Group differences: $F(3, 21) = 4.96$, $p = .011$.

Problem 6: Caregivers need trend and macro-level information to inform Situational Awareness (SA), sensemaking, and decision making, but this information is not available.

Requirements:

- The system shall provide a time-history of trend information at selectable time scales for key patient measures/parameters.
- The system shall provide a top-level dashboard of defined parameters that visually represents each patient's history on those parameters for present day, over the past week, over the past month, and at other time scales (need input from burn unit partners).
- The system should include tripwire algorithms that will flag and notify team of a trending decline or emergent instability in patient health or progress.

Validation Summary: Respondents agreed that they need trend and macro-level information to inform their situational awareness. Overall, respondents indicated that trend information at selectable time scales for key patient parameters would be important; however, nurses indicated that this feature would be moderately important, physicians and therapists identified this feature as important, and others indicated it would be extremely important. Respondents also rated as important a top-level overview that visually represents patient history over time. In addition, they indicated that a CCS feature that flags and notifies the team of a trending decline or emergent instability in a patient would be important or extremely important (see Table 8).

Table 8. Survey Data Pertaining to Problem 6

Challenges Question	Mean Response (SD)	Response Category	Group Difference
We need trend and macro-level information for each patient to help us understand what's going on with our patients and the unit as a whole.	4.13 (0.95)	Agree	No
Potential Features Question			
Trend information at selectable time scales for key patient parameters.[a]	3.84 (0.80)	Important	Nurses = Moderately Important
			Therapists/Physicians = Important
			Other = Extremely Important
Top-level overview that visually represents each patient's history over time.	4.00 (0.91)	Important	No
Flag and notify team of a trending decline or emergent instability in a patient.	4.52 (0.57)	Important – Extremely Important	No

[a] Group differences: $F(3, 24) = 6.17$, $p = .004$.

Problem 7: Team members lack SA regarding who is available on the unit to provide support at any given moment.

Requirement: The system shall maintain an accessible list of team members on the floor at any given time by role and name.

Validation Summary: Respondents agreed that they often lack situational awareness regarding who on the clinical team is available at any given moment on the unit. Respondents indicated that having access to a list or diagram of staff members available at any given time would be moderately important (see Table 9).

Table 9. Survey Data Pertaining to Problem 7

Challenges Question	Mean Response (SD)	Response Category	Group Difference
We are often unaware of which members of the clinical team are on the unit at any given time.	3.71 (1.23)	Agree	No
Potential Features Question			
List or diagram of staff on the floor at any given time by role and name.	3.13 (1.26)	Moderately Important	No

Problem 8: Procedure preparation: When patients are being prepared for a procedure, there are several pre-requisite steps (i.e., have they received blood products, antibiotics, consent, pregnancy test), but there is no means for team members to track and communicate status/completion/readiness for procedure. Lack of SA on this preparation causes delays and wasted time.

Requirements:

- The system shall enable caregivers to select, modify, and annotate completion of prerequisite steps.
- The system shall enable the care team to remotely access this checklist for situation awareness.

Validation Summary: Respondents neither agreed nor disagreed that there is no easy way for team members to track and communicate status and completion of tasks before an OR procedure. They indicated that the ability to select,

modify, and annotate completion of prerequisite steps would range from somewhat important to extremely important. Overall, respondents rated the ability to access remotely the status of prerequisite steps as important (see Table 10).

Table 10. Survey Data Pertaining to Problem 8

Challenges Question	Mean Response (SD)	Response Category	Group Difference
There is no easy way for team members to track and communicate status and completion of tasks before an OR procedure (e.g., orders for blood products and antibiotics, consent, pregnancy test).	3.17 (1.20)	Neither Agree nor Disagree	No
Potential Features Question			
Select, modify, and annotate completion of prerequisite steps (e.g., steps that must be completed prior to surgery).[a]	3.92 (1.04)	Important	Therapists = Somewhat Important – Moderately Important
			Nurses = Important
			Physicians = Important – Extremely Important
			Other = Extremely Important
Ability to remotely access prerequisite steps and see whether they have been completed.	3.76 (1.05)	Important	No

[a] Group differences: $F(3, 24) = 6.97$, $p = .002$.

Problem 9: Both OR and bedside nurses lack SA about OR procedures to enable the most appropriate care to the patient before, during, and after procedures.

Requirement: The system shall provide access to knowledge about procedures given to burn patients, specifying the top risks/care considerations that require understanding and action for those procedures.

Validation Summary: No "Challenges" survey question directly addressed this problem. Nurses, therapists, and physicians indicated that access to patient care considerations after OR procedures would be important. Others rated this potential feature as extremely important (see Table 11).

Table 11. Survey Data Pertaining to Problem 9

Potential Features Question	Mean Response (SD)	Response Category	Group Difference
Access to patient details specifying the top risks/care considerations after OR procedure.[a]	4.04 (0.69)	Important	Nurses, Therapists, Physicians = Important
			Other = Extremely Important

[a] Group differences: $F(3, 23) = 3.95$, $p = .023$.

Problem 10: Lack of SA (availability, accessibility, who is responsible, what is completed) on checklists for daily plan of care created during rounds for patient.

Requirement: The system shall enable a patient's care team to easily document/develop, access/track, update completion, insert material from previous days, and comment on the patient's plan of care checklist.

Validation Summary: Respondents neither agreed nor disagreed that the BICU team has no effective means to track items on patients' daily plan of care. However, they indicated that the ability to easily insert, access, and track material from previous days, and comment on patient status is important (see Table 12).

Table 12. Survey Data Pertaining to Problem 10

Challenges Question	Mean Response (SD)	Response Category	Group Difference
The BICU team has no effective means to track items on the patients' daily plan of care created during rounds (e.g., who is responsible, or whether items have been completed).	2.88 (1.12)	Neither Agree nor Disagree	No
Potential Features Question			
Easily able to access and track material from previous days.	4.17 (0.70)	Important	No
Enables a patient's care team to easily insert material from previous days.	3.96 (0.75)	Important	No
Ability to comment on the patient's status (e.g., plan of care, values in medical record).	3.83 (1.09)	Important	No

Open Narrative Comments

Respondents reported that multiple record-keeping systems requiring redundant data entry make decision making, coordination, and patient care difficult and inefficient. A technology that allows staff to capture patient care activities more efficiently in real time would greatly improve patient care. Such a system would allow staff to spend more time bedside and would help to ensure that treatment plans are still appropriate. Respondents indicated that real-time patient care information must be easily accessible by all treatment team members. Respondents expressed some concern about using a new communication technology. Specifically, they reported concern that

- System use will overshadow patient care
- The system will not be generalizable to other care settings (e.g., trauma and critical care)
- The system will not be compatible with existing Army information system infrastructure
- The system will be redundant with Essentris

Other respondents reported that difficulties working in the BICU result from interpersonal factors. For example, involving outside staff (e.g., orthopedics) in patient care can make accessing information more difficult. However, BICU staff may find it useful to include some outside staff (e.g., pharmacy) during some patient care procedures (e.g., morning rounds). Regardless of the staff members involved, poor communication can disrupt work. Better communication during the hand-off between off-going and on-coming staff and in most other interactions would help improve efficiency and patient care.

Conclusion

Two-thirds of survey respondents reported having difficulty finding information on the BICU at least once. This difficulty often stemmed from technology issues, such as hindered access to information or information missing from electronic sources. Respondents addressed difficulties by seeking support from other staff members.
Respondents generally agreed with challenge statements derived from previous interviews with BICU personnel. The challenge they agreed most strongly with was the need for an effective means to synchronize different aspects of patient care and adjust the care plan over the course of a shift and across the caregiver team (Problem 1). They also agreed that care documentation reduces or compromises time they could spend with patients (Problem 4).

The respondents neither agreed nor disagreed with the following statements:

- It is often difficult to find the information we need to do our work.
- We are often uncertain about whether orders have been placed/entered and whether an order is in process or is complete. [Problem 3]

- We often do not know when an order has been updated or changed. [Problem 3]
- There is no easy way for team members to track and communicate status and completion of tasks before an OR procedure (e.g., orders for blood products and antibiotics, consent, pregnancy test). [Problem 8]
- The BICU team has no effective means to track items on the patients' daily plan of care created during rounds (e.g., who is responsible, or whether items have been completed). [Problem 10]

Despite not necessarily agreeing with all of the challenge statements, respondents rated the vast majority of potential CCS features to mitigate identified challenges as important to their ability to make good and timely decisions, coordinate with their team, and provide effective patient care. The features they rates as most important included:

- List of goals that are prioritized (Problem 1).
- Ability to document information in one common location; information elements then populate other data entry systems as needed (Problem 4).
- Flag and notify team of a trending decline or emergent instability in a patient (Problem 6).

Appendix H1. Open Narrative Responses Organized by Topic

Difficulty Finding Information:

What happened?

- Firewalls on search engines
- Policies, numbers
- Using Essentris, opening several notes to find no plans
- CHCS to find lab values, Endotool not on all computers
- Finding labs quickly
- Finding information from orthopedics, cardio, and other services not collocated at BICU
- No recording of % open wound when I started working in the BICU
- As civilian, being granted access to programs and comments took > 1 week
- As Chief Nurse, I do not have regular everyday access to all clinical information systems
- Not having access to CHCS or other programs requiring a password.
- Finding standards written for what we do (i.e., wound care in the past)
- Policy resources (explaining to residents, "What __ is the first line pressor.")
- Frequent difficulty finding POC in general
- At times difficulty finding specifics ("Why we __ and when to __.")
- Difficulty getting some results (labs).

How did you find it?

- Asked other people to find out
- I usually called staff involved, but don't always find them immediately.
- Went to staff to find out [follows "% of open wound" comment above].
- [follows "difficulty finding specifics" comment above] Generally required physically finding staff who ordered the intervention. Not always feasible.

If you couldn't find it, what did you do?

- [follows "% open wound" comment above] Ended up with weekly meetings with wound care specialist.
- [follows "% open wound" comment above] Helped develop WoundFlow.
- [follows "programs requiring password" comment above] Notify charge nurse.
- [follows "programs requiring password" comment above] Notify the right department.
- [follows "programs requiring password" comment above] Go downstairs when I get a change, get a new password.

Additional challenges that hinder effective decision making, coordination, and patient care:

- All aspects of patient care are done in a safe effective way with work-around for each task. The work-arounds are effective and are built into the day. Decreasing or eliminating these will require a cultural change in the staff.
- Information I need or staff members are usually available except when outside staff is involved, especially orthopedic services.
- The fact that we have three electronic records systems is ridiculous
- The only thing I would change would be the addition of pharmacy participating in morning rounds.
- Care document would be greatly enhanced by a tablet used to capture real-time patient care activities

- Over the years, too much paperwork/chart affiliated work has been placed on nursing. I've been pulled away from the bedside for non-essential, yet mandatory charting.
- Double documentation is a definite problem. Documentation requirements constant change in our environment. However, the BICU Checklist and Dr. Pamplin's implementation of the phases of Ulkei have been very useful in keeping some of this information easily visible.
- Benefit of updated orders during SM rounds and following up with PRN rounds to changes depends on who is in charge of rounds for the day.
- Often times there is very poor communication between attending staff. Would be good for the off-going and on-coming to physically round and complete a true/better type of hand-off.

Additional thoughts regarding Potential Features survey items:

- 1. Nursing care plan? Nursing's would be a '1'. Nursing Care Plan (Nurse clinical shift notes) is a waste of time.
- 19. We (staff nurses) should know as well.
- 26. Should be readily available.
- For doctors: No way of capturing whether a lab/procedure has been done/sent, aside from asking the nurse or by checking in CHCS. More often, nurses are looking for a physician to notify of problems but are unable to locate them in a truly timely fashion. There should be some staff notification when all MDs are off the unit at any given time, and a plan for back-up.

Additional features that would help you in caring for your patients:

- "Real time" updating of patient status would greatly improve patient care.
- I need to know if my treatment plan is still appropriate in the amount of stress to overall patient status and particularly to wounds. That is the information I need updated, easy access to each day, throughout the day. The bedside nurse is my first line of getting this information and as long as that person is updated and I am updated.

Other Concerns:

- Concerned that updates and notifications will become more important than the task, order, and patient.
- That the system being developed be generalizable throughout trauma and critical care.
- That the system can function without compromising the ARMY Information System Networks.
- A lot of the "system features" are available if you know how to navigate Essentris. I don't think the "Patient severity of illness" is helpful to the bedside nurses…perhaps the MDs, who rarely interact with the patients. Nursing already knows most of that information.

Appendix I. Data Requirements

Based on the synthesis and integration of findings, the team developed an initial set of system requirements for CCS using the following framework:

- What is the barrier or challenge the clinical team faces?
- What does the clinical team need/require to overcome that challenge?
- What system or display features could help address that challenge?
- What is the anticipated impact of meeting that requirement on team coordination, efficiency, and patient care?

This appendix contains the full set of initial requirements, the problems they are intended to address, the system features suggested by requirements, and initial ideas about how system features might impact patient care, efficiency and length of stay.

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
No effective means to synchronize and adapt different aspects of patient care over the course of a shift (e.g., among RN, OT/PT, wound care) Lack of awareness around activities/ events that are tightly coupled No efficient communication of patient status change across disciplines	• Need to determine optimal timing and sequence of activities • Need awareness of planned/scheduled patient care activities (e.g., wound care, rehab, line changes, etc.) • Means to share the plan • Means to adapt the plan in real time and share changes across the team. • Bedside nurse needs to shift the goals and priorities • Means to know how changes in orders affect/change planned activities • Means to know what planned events are and who needs to be there • Practitioners need to understand what's going on with their group of patients across the shift (whatever their group happens to be)	• Visualization of patient schedule for shift (patient x time), shareable across team • Ability to sequence or overlap patient care activities • Configurable patient groupings • Prepackaged text to indicate changes to schedule (e.g., there's a ½-hour delay in PT) • Sequence, time of planned activities • Provide reason for delay, and remedy (using pre-packaged text) • Overview through time, for unit management • Visually connect interdependent events • Prompt/notify appropriate person when change impacts their activity (e.g., when wound care impacts PT/OT and RT)	• Patients get needed care with fewer delays • Efficient use of staff time • Reduces unmet treatment plans and intentions • Supports replanning – helps staff identify windows of opportunity

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
Updated information is available but not readily accessible or visible to clinicians (e.g., cultures)	• Clinicians need to be aware that updated information is available, particularly re: lab cultures	• System provides news feed from lab about cultures. • Red/amber/green about status of labs (received or not; in progress; completed)	• Fewer care delays • More efficient tracking and follow up • Better use of staff time • Less reliance on verbal exchanges
Orders late, missing, or overtaken/replaced by other orders Reliance on verbal orders and no standardized way to share orders	• Need efficient, accurate way to specify meds, procedures • Physicians need access to orders from Charge Nurse's checklist • Physicians need prompts to enter orders • Need indicator of status of order entry (has it been placed or not?) • Need indicator of status of order (in process, completed) • Physicians need to be aware when entering order that it's the same as or different from previously entered orders • Changes to orders need to be disseminated to wider team so that team has common ground. Changes in orders need to be apparent to whole team	• Order pick list and window per patient to support real-time order entry during rounds • Order status (have orders been received? Completed?) • Notify others if needed (e.g., infections control) • Provide prompt for delayed order entry (based on programmable timing tripwire) • Display the information required to make decisions about an order available with the order (the relevant parameters) • Provide molar/aggregated view of delays for a given patient • System will track (and possibly highlight) when an order has been changed. • System will provide timestamp for orders	• Fewer care delays • More efficient order entry and tracking • Better use of staff time – reduced need for repeated follow-ups • Reduced reliance verbal orders

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
Documentation requires significant time from key members of the clinical team (RNs, Residents, RTs etc.) and is often redundant	• Information Management tools and processes built around efficient use of staff time and effort • Minimize staff time required to capture information by reducing redundant information gathering and entry • Minimize staff time spent as the 'system integrators' who move data from one system to another • Need 'user-friendly' interfaces/systems	• System built on a relational database that has all the information relevant to a given patient, so that there is true interoperability: ability of separate systems to cross-populate data, in real time • System supports capturing and displaying time-based, patient-based, unit-based data • Interfaces support simple data entry and pulling information (faster, more efficient documentation; errors/disconnects more easily spotted) • System's ability to recognize 'repetition' when new documentation is introduced (e.g., 'we already capture that data over here') • System features that scan new documentation requirements for novel information/redundancies (don't just add more)	• Decreased time spent entering, moving, repeating, re-entering, data • More time with patients; increased ability to attend to patient issues and needs • Decrease cognitive workload • Decrease in potential data entry errors (repeated entry of same data increases chance for error)
Lags in information updates means information in system is sometimes stale/inaccurate	• Means to indicate if patient is highly unstable (because information for unstable patients can become inaccurate in short timeframe) • Means to know whether information in system is up-to-date (e.g., is this an accurate reflection of the patient's status right now?) • Means to know whether orders are in process but results not entered into system yet (e.g., cultures, lab results) • Means to know recency of information updates • Means to capture and disseminate changes to orders that occur verbally within sub-teams	• Information should be time stamped (Q: which information in particular?) • System should highlight recent results—e.g., lab results, cultures. And also highlight orders that are in process • System should highlight/provide alert when orders are changed • System should highlight/alert staff to contraindications (e.g., patient positioning, nutrition)	• Optimized patient care • Better use of staff time – reduced need for repeated follow-ups • Reduced reliance verbal orders • Reduced potential for error

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
Trends are important information, but can't get them from Essentris or other IT. No ability to keep track of patient status over time > 24 hours.	• Clinicians need trend information • Need view of patient that is more than just this shift. Both macro level view of indicators and over longer time spans	• System should display trend information for key parameters (to be identified by clinical staff) • System should provide trend information over different time slices • Provide access to views of patient beyond current 12 or 24 hours	• Optimized patient care • Increased ability to spot changes in patient status, intervene more quickly
What clinical staff are currently on the unit?	• Need to know who is available, and where to find them • Need access to nurse assignments by shift, by patient • Means to access assistance, guidance, decision makers • Need to know which specialty is assigned to each patient (e.g., RT) and patient acuity	• Names of who is working on unit that day, with patient assignments by room • Call/staff assignment roster • Shareable across disciplines • Map view of floor and display showing location of staff. • Text paging/pre-populated messages • ID with RFI tag	• Allows staff to readily know who is available so they do not spend time away from patient trying to locate staff • More efficient communication • Mitigates care delays • Can get help when it is needed
Is patient ready for upcoming surgical procedure	• Need means to know whether patient is prepared for procedure (have they gotten blood products, antibiotics, consent, pregnancy test)	• Provide roster of needed items (e.g., blood, antibiotics) and indication of whether those items have been satisfied	• Prevent delay in procedures

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
OR RN does not know enough about upcoming procedure to prepare surgical suite properly Bedside RN does not know enough about surgery as it is being performed to prepare properly for patient's return	• OR nurse needs procedure specific description (need to know more about specific information needs) • Bedside Nurse needs means to know what to expect re patient needs following procedure (e.g., what was worked on, how much blood given or lost, sedation?)	• Provide information about intended procedure • Provide information about surgery in process and patient status	• Nursing staff better prepared to care for specific patient needs at earliest opportunity
Rounding Checklist not readily available/accessible to all members of clinical team Impact of dropped tasks, gaps, and lapses not known or tracked Checklist management is unclear (responsibility for making sure items are completed is unclear).	• Means to construct checklist in real time (during Rounds) or immediately after • Means to post checklist so all staff have ready/easy access • Means for staff to 'check off' completed items, makes notes re: hold ups, changes/revisions • Means for incomplete items to 'roll over' to populate next day's check list and to be reviewed at next-day Rounds	• Checklist needs to interact with order and other clinical systems • Unit level view that is easy to access and track • "Roll up" function: ability to look across patients/shifts/types of activities to examine when there are particular activities consistently missed/delayed; or care for a particular patient consistently delayed • System supports task tripwires (e.g., timing). Ability to recognize disconnects between orders and implementation (e.g., order entered, but not reviewed) • Provides alerting function when tripwire is crossed • Tripwires are definable by the staff	• Fewer care delays • More efficient order entry and tracking • Better use of staff time • Reflect on/improve on checklist performance • Potential unintended consequence: alarm/alert fatigue

Problem/Barrier	Needs/Requirements	System Feature Concepts	Anticipated Impacts
Reliance on clinician to mentally integrate data	• Clinicians need a holistic/macro-view of the patient's trajectory (e.g., are they getting better or getting worse over last 24 hrs.?)	• Provide trend data and key indicators (e.g., for each of the main bodily systems) • Trends on vitals, wound healing, medication dosing, infections	• Clinician better able to focus on problem detection, anticipate need for changes in treatment plans, optimize decision making around patient care

Appendix J. Society of Critical Care Medicine (SCCM) Poster

Developing a Cooperative Communication System for Safe, Effective, and Efficient Patient Care

Christopher Nemeth, PhD[1], Shilo Anders, PhD[1], Jeffrey Brown, M.Ed[1], Beth Crandall, BS[1], Anna Grome, MS[1], Maria Serio-Melvin, MSN[2], Elizabeth Mann-Salinas, PhD[2], Jeremy Pamplin, MD[2]

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Introduction

Traditional quantitative research designs do not sufficiently account for the complexities of individual and team decision making in the ICU work domain.

We used a mixed methods Cognitive Systems Engineering (CSE) research approach to produce a model of cognitive work that guides IT solutions to support clinical work, making decisions more accurate, reliable, and efficient.

In the past 12 months we addressed these questions:

- What activity(ies) should a computer-based decision support system assist?
- What should a display look like? How should it behave?

Aim/Objective

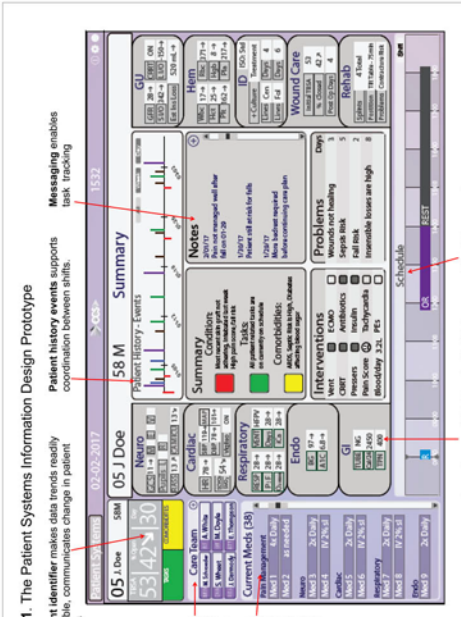
To improve care by supporting clinical decision-making through the design and development of valid computer-based decision support and communication tools.

Methods

Our 2013 research included 5 week-long observation visits to a 16 bed regional referral Burn ICU in a 450-bed academic military medical center. These visits occurred over one year and included artifact analysis, multiple structured interviews, data analysis sessions, and surveys. This foundation research has guided project activity during 2014:

- **Developed Information design**—Created graphic user interface (GUI) views based on 39 CCS requirements developed during the first phase.
- **Assessed validity**—Reviewed versions of the information design prototype with a select number of clinicians at the research site to ensure GUI continuity with the clinical work setting.
- **Developed software prototype**—Our software developers used the information design prototype to guide creation of the first version for the user interface.
- **Created development environment**—Developed a separate operating system so that the software prototypes can have access to patient data, yet remain entirely separate from actual databases.

Figure 1. The Patient Systems Information Design Prototype



Discussion

Here is how CCS Patient View enables clinicians to overcome barriers:

- **Unified view** spares clinicians from need to integrate data, lessens errors (e.g. wrong orders) unit members need to rectify, drives down documentation time as IT processes frequently require redundant information capture.
- **Care team** roster matches resources to needs, and resource availability knowledge (e.g. who is on unit).
- **Accurate current display of salient data** communicates change in patient status across disciplines; makes current information available.
- **Patient history events** supports coordination between shifts. Data trends are readily available.
- **Messaging** enables task tracking, clarifies responsibility for task completion, lessens reliance on nurses to track and fix information gaps/resolve conflicts, delayed, missing, or replaced orders, reliance on verbal orders.
- **Meds and orders** lessens time spent tracking down in-process items like meds and lab, delayed, missing, or replaced orders, as rounds checklist is not available to all members.
- **Schedule** enables synchronization of care, awareness of coupled activities, coordination between the BICU and OR.

CSE methods can reveal the nature of work as it is actually done, and when it is done, by those who do it. This makes it possible to create effective solutions that workers recognize and readily accept.

Results

We discovered 21 barriers to effective patient care:

- Synchronization of care
- Awareness of coupled activities
- Communicating patient status across disciplines
- Availability of current information
- Delayed, missing, or replaced orders
- Reliance on verbal orders
- Coordination between shifts
- Documentation time
- IT process often require redundant information entry
- Data trends not readily available
- Clinicians must integrate separate data sources
- Resource availability (e.g. who is on the unit)
- Coordination between the BICU and OR
- Rounds checklist not available to all team members
- Tracking of dropped tasks;
- Unclear responsibility for task completion
- Time spent tracking down in-process items
- Reliance on nurses to track and fix information gaps/resolve conflicts;
- Matching resources to needs;
- Errors (e.g. wrong orders) unit members must rectify.

We developed 39 requirements for the CCS software to overcome these barriers that informed information design prototypes of graphical user interfaces (GUI) features and views.

- **Patient Identifier** *(upper left corner)*—Graphic identifier with key status data
- **Unit View**—Floor plan showing patient location, incorporating patient identifier, messaging
- **Rounds CRN** *View*—Supports Charge Nurse interdisciplinary rounds preparation, participation
- **Messaging**—Real-time support for correspondence among care team members
- **Care Team Manager**—Window to assign staff members to unit duties
- **Scheduling**—Representation of activities planned for unit, by patient, through the day

Programmers are using the prototypes to develop the GUI that is being evaluated in the BICU. *The Patient Overview* example (Figure 1) summarizes salient patient data.

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Appendix K. SSCI Activity Summary

During Year 1, subcontractor SSCI worked on initial ML aspects of the CCS.
The following text is SSCI's summary of their activity.

- SSCI personnel worked with ARA development team to establish cooperative development facilities, procedures, and schedules.
- SSCI personnel worked with Dr. Pamplin to further refine the overall expected progression and methodologies for the project.
- SSCI personnel participated in a brainstorming session (on site at ARA Dayton) which resulted in a mockup of the CCS GUI.
- Collaborating with medical personnel at USAISR, and performing knowledge extraction and representation design, SSCI developed the user-level use cases that have driven the development of the analytics tools for the CCS prototype.
- SSCI developed user-level use cases into functional requirements.
- SSCI constructed a draft API for the data analytics module.
- SSCI developed technology to create artificial data cohorts, given the sparseness of data made available to the team in year two.
- SSCI gathered data from previous and ongoing projects and used those data to test components (also to support project progression given the sparseness of available data).
- SSCI constructed a preliminary set of Developer-Level Use Cases based on the components above. These served as the foundation for immediate development activities.
- Based on these preliminary documents, and ARA's preliminary software architecture, SSCI developed a basic framework to demonstrate the implementation of SSCI technologies. The framework was developed in stages of increasing features: running of SSCI technologies in a background thread, reading and writing data from relational databases and finally, basic interaction with a sample HTML webpage to mimic the user-level use cases.
- SSCI collaborated with ARA on a set of Functional Requirements for the CCS prototype.
- SSCI performed an extensive analysis of the Deceased Patient Data, identified issues and documented results.
- After developing the key Patient Condition Point concept, SSCI developed the translator that builds a CCS Patient Condition Database from the Deceased Patient Data loaded into an Essentris Database.
- SSCI led efforts that determined (collaboratively with the CCS team) the subset of data fields in Essentris that, for purposes of the prototype, define a Patient Condition Point.
- SSCI developed techniques for deriving and representing trend data as a part of the central Patient Condition Point concept.
- SSCI constructed a test harness for the CCS prototype data analytics components.
- SSCI delivered to the USAISR a series of installation packages for their development environment to test execution of the critical components of the SSCI software. The tests were successful.
- SSCI completed in-processing at the USAISR and acquired log-in credentials on the development environment.
- SSCI delivered, tested and demonstrated an operational installation of the SSCI software on the development environment at the USAISR, including a working interface to the CCS GUI.
- SSCI participated in significant re-planning of the project as its requirements and constraints evolved throughout year two.
- SSCI representatives attended weekly project management meetings.
- SSCI representatives attended weekly developer team meetings.

- SSCI representatives performed several demos to the overall project team to facilitate refinement of the CCS prototype data analytics modules.
- SSCI representatives attended ad-hoc meetings on site at USAISR.

Appendix L. CCS Glossary (Draft)

Cognitive and Human Factors

Term	Definition
Clinical Decision Making	Individual and team cognitive work, including macrocognitive activity that clinicians perform to return patients to best possible health. Spans individual, care team, and unit levels.
Cognition	The mental action or process of acquiring knowledge and understanding through thought, experience, and the senses.
Cognitive Task Analysis (CTA)	A variety of techniques that can be used to assist human performance in cognitive work (i.e., work having to do with problem solving and decision making; Nemeth, 2004, HFMD 196).
Cognitive Systems Engineering (CSE)	The creation of systems based on understanding human cognition (Woods & Roth, 1988). The design of information systems for support of people in their actual work situation based on a systematic analysis of their cognitive tasks and their mental strategies. An approach to the design of technology, training, and processes intended to reduce cognitive complexity in sociotechnical systems (Militello, Dominguez, Lintern, & Klein, 2009). Process of learning about behavior as humans confront complexity in their work settings, and providing tools to support their behavior (ESMF Briefing, 2011). An effort to support the cognitive requirements of work - primarily applied to design of information technologies to make them easier to use and more likely to be adopted. (i: drive slide deck (Dominguez, Klein, Fallon, Militello, & Lintern). A design approach aimed at improving cognitive work by linking system features to the cognitive processes they need to support.
CSE Process	Five-phase approach to ensure ecological validity of solutions that are intended to support cognitive work. Preparation yields domain understanding. Knowledge Elicitation identifies key decisions. Data Analysis and Representation specifies leverage points. Application Design creates concepts. Evaluation estimates concept effects (Crandall, Klein, & Hoffman, 2006).
Decision-Centered Design	Use of cognitive task analysis to develop complex human-machine systems to specify primary cognitive requirements and inform the design process (Crandall, Klein, & Hoffman, 2006:177).
Decision Support Systems (DSSs)	A computer-based information system that supports operational, business, or organizational decision-making activities.
Human Factors	The development and application of knowledge about human physiology and behavior in the operational environment. Draws on knowledge from a variety of fields (e.g., Psychology, Sociology, Design, and Industrial Engineering) and methods to develop systems that are user centered (Nemeth, HFMD, 2004:26).
Information Design	Optimal presentation of salient alpha-numeric and visual information to support decision making.

Term	Definition
Salient Information	Information that is important. Importance depends on context, and user intentions/goals. Presentation and comparison of important information will support more accurate, efficient decision making.
Sensemaking & Sensegiving	The process by which people give meaning to experience (Wikipedia). Developing a "vision" or mental model of how the environment works (sensemaking) and then communicating to others that understanding (sensegiving).
Traditional Human-Computer Interaction (HCI)	Human–computer interaction (HCI) researches the design and use of computer technology, focusing particularly on the interfaces between people (users) and computers. Researchers in the field of HCI both observe the ways in which humans interact with computers and design technologies that lets humans interact with computers in novel ways (Wikipedia).
Requirements	Characteristics that are necessary or essential, and set the stage for the creation of a product (Nemeth, 2004, HFMD:10).
Resilience Engineering	Engineering practice that increases a socio-technical system's adaptive capacity so that it can continue to function in the face of unforeseen challenges.
Research Design	The structure and process that are used to seek answers to research questions.
User-Centered Design	Considers both the human and the technical subsystems in the broader context. Users are typically consulted throughout the design process. The user-centered approach has been applied to product production, particularly in human-computer interaction (Nemeth, HFMD, 2004:6).

Organization Acronyms

Term	Definition
ARA	Applied Research Associates
CDMRP	Congressionally Directed Medical Research Program
CSD	Cognitive Solutions Division
JPC-1	Joint Program Committee -1: Solving Complex Healthcare Problems Using Technology
SED	Southeast Division
USAISR	United States Army Institute for Surgical Research

Clinical

Term	Definition
Clinician	Any healthcare provider who delivers care to a patient.
PACU	Post-Anesthesia Care Unit: A post-anesthesia care unit, often abbreviated PACU and sometimes referred to as post-anesthesia recovery or PAR, is a vital part of hospitals, ambulatory care centers, and other medical facilities. It is an area, normally attached to operating theater suites, designed to provide care for patients recovering from anesthesia, whether it be general anesthesia, regional anesthesia, or local anesthesia (Wikipedia).
GI	Gastrointestinal.
CARDIO	Cardiology (study of the heart); also CV for cardiovascular.

Term	Definition
Heme	Hematology (study of the blood).
BICU	Burn Intensive Care Unit.
CICR	Comprehensive Intensive Care Research task area.
ID	Infectious Disease.
Endo	Endocrine: to the collection of glands of an organism that secrete hormones directly into the circulatory system to be carried towards a distant target organ (Wikipedia).
GU	Genitourinary: In anatomy, the genitourinary system or urogenital system is the organ system of the reproductive organs and the urinary system. Burn patient physiology tends to focus on the urinary system, which encompasses fluids and electrolytes as well as renal function (clearance of toxins and metabolites).
IMD	Information Management Division.
TEN	Toxic Epidermal Necrolysis: Also known as Lyell's syndrome, is a rare, life-threatening skin condition that is usually caused by a reaction to drugs. The disease causes the top layer of skin (the epidermis) to detach from the lower layers of the skin (the dermis), all over the body, leaving the body susceptible to severe infection (Wikipedia).
RESP	Respiratory: (also called respiratory apparatus, ventilatory system) a biological system consisting of specific organs and structures used for the process of respiration in an organism. The respiratory system is involved in the intake and exchange of oxygen and carbon dioxide between an organism and the environment (Wikipedia); also "Pulm" for "pulmonary."
Rehab	Rehabilitation.
Charge Nurse	A nurse responsible for supervision of nurses on each shift and making sure nursing care is delivered safely and that all the patients on the unit are receiving adequate care. They are typically the frontline management in most nursing units (Wikipedia).
Wound Flow	"A system providing electronic burn mapping for documenting full and partial thickness burns and ongoing surgical treatment modalities." http://technologytransfer.amedd.army.mil/assets/docs/abstracts/factsheet_WoundFlow.pdf
Essentris	Inpatient electronic health system use in acute hospital environment, providing point-of care data capture at the patient's bedside for physiological devices, feta./uterine devices, ventilators and other patient care machines. (http://www.health.mil/~/media/MHS/Fact%20Sheet%20Files/DHCS/Garrison/Essentris%20fact%20sheet.ashx)

CCS

Term	Definition
Alerting	This feature combines rules related to tracking information and clinician activity and providing push notifications ("alerts") according to changes in information or at the request of team members.
CCS	Cooperative Communication System.
Care Team Manager	CCS widget that is used to assign staff members to patient care responsibilities Notes: A patient's schedule to be filled with clinicians and teams to participate in the patient care. Chris N: Idea is to enable the team to schedule each patient for care. Example: The role of the bedside nurse, the burn surgeon, related to the patient. Dr. Pamplin could get assigned to the attending today but also the burn surgeon. In the nurse role you might have more than one nurse for today. Jeremy: My concept of role is different. In Josh's mind physician is a role – the clinical is I'm a physician but could be the burn surgeon, unit attending, researcher, etc.
Messaging **PI Form calls this 'Communication widget'**	Real-time support for correspondence among care team members. 1. To improve clinicians' situational awareness about a patient/patients assigned to their care 2. As an alternative communication method; in situations where voice, phone and pager communication are limited. 3. To provide an avenue to communicate safety concerns without fear of judgment or retribution (to avoid "the Silent Treatment").
Configurable Editor/ Information Display	A configurable feature of CCS that will allow clinicians to customize the Patient View with important data they prefer to see to support their decision making.
Family View	CCS interface screen intended to provide those who are related to the patient with information on patient condition and progress.
Module	A collection of system features that can be used to plan and manage development activity. In the case of CCS, each module is comprised of specific widgets to be completed by a certain date.
Orders Widget	Coordinating, accounting for, and adjusting medications, therapies, and investigations a significant amount of both cognitive and physical activity in an ICU (and likely other work domains).
Patient Identifier Widget	Simple display included in each CCS screen to identify information that pertains to an individual under care in the BICU. Includes indication of recent health trend, current patient problems/diagnoses as well as changing patient condition (e.g. "better," "same," or "worse"). To build the Patient ID component of the CCS, designed to improve the efficiency and resiliency of the Burn ICU by providing leadership and clinicians with an overview of each individual patient's status, and on the larger scale, helping them to gain insight into the status of the overall unit.
Patient Schedule	Allocation of resources depending on who's available from the Unit Schedule. The representation of activities planned for unit, by patient, through the day.
Patient View	A view of salient data for each patient admitted for treatment in the Burn ICU. Clinicians can customize the data they prefer to see to support their decision making.

Term	Definition
Charge Nurse View	Page to support Charge Nurse preparation for and participation in interdisciplinary rounds.
Rounds Review	Summary of Charge Nurse entries in Rounds CRN View, by patient
Scheduling Widget	Beginning representation of activities planned for unit, by patient, through the day. Allows the joint cognitive system to better plan and coordinate care dynamically
"Smart" Checklists **Checklist Widget**	Provides a means for the computer to track quality metrics in real-time. Checklist items may be identified from data in the EHR in which case "faults" are pushed to clinicians or items may be displayed as clinical reminders or "considerations" for clinicians to use when making decisions.
Staffing	Staff scheduling software, using the ScheduleAnywhere software widget, which makes it possible to know which staff members are available for assignment. Supports use of the Care Team Manager widget, which assigns staff roles or available staff members to patient care responsibilities Produces a Patient Schedule, shown in each individual Patient View, that depicts planned care activities through the day.
Tab	A means of interaction with the user interface that organizes information elements and can be chosen in order to select one group or another.
Tasking	Work assigned to a BICU team or team member.
Unit Schedule	The assignments of clinicians to task by shift. A summary of all the patient schedules.
Unit View	An aggregate view of all patients on the floor, organized according to the BICU floor plan.
User Manager	The feature that is used to identify a team member in the CCS. Enables a team member to express personal preferences for how they would like to interact with the system. Example: Dr. Pamplin can be placed in the following roles: surgeon, lecturer, 4 East Attending, etc.
View	A screen in the CCS that includes salient information on a topic, such as Patient, Unit, Orders.
Widget	A simple and easy-to-use software application or component made for one or more different software platforms.

Software Development Terms

Term	Definition
Agile Development	Agile software development is a group of software development methods in which requirements and solutions evolve through collaboration between self-organizing, cross-functional teams. It promotes adaptive planning, evolutionary development, early delivery, continuous improvement, and encourages rapid and flexible response to change.
API	In computer programming, an application programming interface (API) is a set of routines, protocols, and tools for building software applications (Wikipedia).
ARFF	A text data format based on comma separated values with metadata annotations for each attribute indicating the type or expected values. This format is used by many ML algorithms and provides a robust way to archive a subset of a database for processing.
Backlog	A list of requirements that is maintained for a product developed using the Scrum methodology (Wikipedia).

Term	Definition
GUI	In computing, a graphical user interface (GUI, sometimes pronounced “gooey” or “gee-you-eye”) is a type of interface that allows users to interact with electronic devices through graphical icons and visual indicators such as secondary notation, as opposed to text-based interfaces, typed command labels or text navigation (Wikipedia).
Java (Programming language)	Java is a general-purpose computer programming language that is concurrent, class-based, object-oriented, [12] and specifically designed to have as few implementation dependencies as possible. It is intended to let application developers "write once, run anywhere" (WORA), [13] meaning that compiled Java code can run on all platforms that support Java without the need for recompilation (Wikipedia).
Machine Learning	Machine learning is a scientific discipline that explores the construction and study of algorithms that can learn from data. [1] Such algorithms operate by building a model from example inputs and using that to make predictions or decisions, [2] :2 rather than following strictly static program instructions. Machine learning is closely related to and often overlaps with computational statistics; a discipline which also specializes in prediction-making (Wikipedia).
PHP	PHP code can be simply mixed with HTML code, or it can be used in combination with various templating engines and web frameworks. PHP code is usually processed by a PHP interpreter, which is usually implemented as a web server’s native module or a Common Gateway Interface (CGI) executable. After the PHP code is interpreted and executed, the web server sends resulting output to its client, usually in form of a part of the generated web page; for example, PHP code can generate a web page’s HTML code, an image, or some other data. PHP has also evolved to include a command-line interface (CLI) capability and can be used in standalone graphical applications (Wikipedia).
Precision, Recall, and Accuracy	Metrics commonly used for evaluating the performance of ML algs. A nice version of the confusion matrix and formulas is here: http://en.wikipedia.org/wiki/Precision_and_recall.
SCRUM	Scrum is an iterative and incremental agile software development methodology for managing product development. It defines “a flexible, holistic product development strategy where a development team works as a unit to reach a common goal,” challenges assumptions of the “traditional, sequential approach” to product development, and enables teams to self-organize by encouraging physical co-location or close online collaboration of all team members, as well as daily face-to-face communication among all team members and disciplines in the project. A key principle of Scrum is its recognition that during a project the customers can change their minds about what they want and need (often called “requirements churn”), and that unpredicted challenges cannot be easily addressed in a traditional predictive or planned manner. As such, Scrum adopts an empirical approach—accepting that the problem cannot be fully understood or defined, focusing instead on maximizing the team’s ability to deliver quickly and respond to emerging requirements (Wikipedia).
Sprint	A sprint is a get-together of people involved in a project to give a focused development on the project. Sprints are typically from one week up to three weeks. A significant benefit of sprinting is that the project members meet in person, socialize, and start to communicate more effectively than when working together remotely (Wikipedia).
Staging Database	A copy of data that has been cleansed (removing issues in the data) and pre-processed for use in multiple analytics. Examples include parsing text views of data to extract numeric data, range-checking, adjusting for consistent units, computing trends, or fusing multiple data elements to create more useful values for analytic processing.

Term	Definition
Supervised Learning	A class of machine learning algorithms that uses a correctly labeled training data set to create an analytical model for labeling new data instances. An example of this is using clinician-labeled problems, learning the features in the data that differentiate the different instances of data for each label, and being able to intelligently label new data instances with similar accuracy. These are often variants of Classifiers.
Temporal Event Sequences	A time-series list of occurrences of relevant situations or actions differentiated by other knowledge representations by its distilling of the sequential ordering rather than summarization metrics. Temporal event sequences are used to represent and reason over instances when the ordering is essential to understanding the story.
Unsupervised Learning	A class of machine learning algorithms that uses identifies similarities in data sets without any classification labels and learns a model for organizing data in a sensible manner. Examples include clustering algorithms. In CCS, the cohort identification is an example of unsupervised learning because there are not identified “correct” cohorts pre-established.
Wire Frame	Also known as a page schematic or screen blue print, is a visual guide that represents the skeletal framework of a website or system interface. Wireframes are created for the purpose of arranging elements to best accomplish a particular purpose. The purpose is usually being informed by a business objective and a creative idea. The wireframe depicts the page layout or arrangement of the website’s content, including interface elements and navigational systems, and how they work together. The wireframe usually lacks typographic style, color, or graphics, since the main focus lies in functionality, behavior, and priority of content. In other words, it focuses on what a screen does, not what it looks like (Wikipedia).

Appendix M. Trip Report: ARA SED Machine Learning Team Trip to USAISR 13-17 April 2015

7 May 2015

From: Chris Argenta
To : Mr. Tony Story, CDMRP
Cc : Jose Salinas, PhD, Army Institute for Surgical Research

Subj : Trip report : AISR In-processing, Patient Descriptive Data Collection and Status Reporting: 13-17 April 2015

1. Executive Summary. Applied Research Associates, Inc. (ARA) is under contract W81XWH-12-C-0126 to the U.S. Army Medical Research & Material Command's (USAMRMC) Telemedicine & Advanced Technology Research Center (TATRC). The Cooperative Communication System is intended to be part of a joint cognitive system that allows the healthcare team to remain connected to an individual patient and to each other across time and space as the team delivers patient care. In addition to the improved communication among providers, this project explores the potential to provide relevant information to support clinician decision making. In order to support decision making, a machine learning effort has been included to identify effective patient treatments based on similarity with prior patients. Initial machine learning efforts include collecting descriptive statistics about existing patient data and developing methods to identify similar patients.

2. ARA Staff. Research personnel on this trip included Chris Argenta, Tony Hamilton, and Bryan Fricke from SED.

3. Activities.
a. Chris and Bryan went through in-processing in order to obtain clearance to work on-site during the trip in order to obtain descriptive statistics about the 2 year patient data set. Tony Hamilton arrived on Tuesday and stayed until Wednesday in order to load both the CCS user interface and machine learning code. After obtaining CAC cards, Chris, Tony, and Bryan worked through some technical issues in order to output descriptive statistics about the patient set. Chris and Bryan requested the code changes and 4 descriptive statistic data files be pulled off of the developer network and provided for download. LTC Pamplin agreed under the condition that he be given access to 4 data files that are pulled off of the developer network. All information was collected in accordance with IRB-prescribed procedures.

b. Chris and Bryan went on rounds with Dr. Pamplin. During rounds, Chris and Bryan were able to observe how patient data is tracked outside of each patient's room. Dr. Pamplin has developed a sort of white board based approach to patient health and chart information. In addition, a computer on wheels is used to access Essentris and WoundFlow for each patient. During rounds interns report patient information, health status, prior day interventions and recommended interventions. Dr. Pamplin evaluates this information to lead interns to appropriate care decisions. In addition, nursing staff, nutrition staff, and other wound care team members

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http://www.ara.com/CognitiveSolutions

participate in communicating previous treatment and planned treatment for a holistic approach to healthcare.

c. Chris and Bryan also participated in several meetings with clinicians to report the status of the machine learning effort and to discuss the methodology for identifying patient cohorts. In one meeting, Randy Frank called in to explain results generated from code that he has developed to identify similar patients. One of the attending clinicians requested we hold a follow-on meeting to continue the conversation about the viability of the approach to identify patient cohorts given the limited and inconsistent data to which we have access.

4. Results. In-processing was completed for Chris and Bryan. Both have CAC cards and are able to gain unescorted access to the facility and develop and run code on the developer network. In addition, code changes and descriptive statistic data files were subsequently delivered from AISR.

5. Further work. Next steps for the project are:

a. Work with LTC Pamplin to obtain clinician evaluations of patient similarity in order to create classification criteria in order to tune and validate the machine learning code.

6. For further information, contact Chris Argenta at (919) 582-3442, or cargenta@ara.com.

Appendix N. Nemeth, C. *Revealing Interdependencies: How Cognitive Systems Engineering Can Improve Resilience*. The 2015 International Symposium on Computational Psychophysiology, Jinan, Shandong Province, People's Republic of China. April 3-6, 2015.

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Revealing Interdependencies

How Cognitive Systems Engineering Can Improve Resilience

Presented by

Christopher Nemeth, PhD, CHFP

To

The 2015 International Symposium on Computational Psychophysiology

Date

4 April 2015

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Objectives for This Session

- Understand how human factors can help to improve healthcare reliability, safety, efficiency, and resilience.
- Learn about Cognitive Systems Engineering
- Understand how use of CSE can improve resilience, using healthcare as an example
- Apply use of CSE to IT development

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Human Factors in High Risk Work Domains

- Human factors applies knowledge of physiology and psychology to create human-centered solutions from work processes to controls and displays, and facilities to assure safe, efficient, resilient performance.
- Aviation/aerospace, military, high speed ground transportation, nuclear power generation, healthcare
- Time-pressured, complex, resource-constrained, poorly bounded, uncertain, evanescent. No single person's knowledge is adequate. Stakes are high.
- Healthcare is a good example I'll use today

Nemeth, C. (2004). *Human Factors Methods for Design*. Boca Raton, FL: Taylor and Francis/CRC Press

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Theory: Joint Cognitive Systems

- Assembly of elements intended to accomplish a desired goal that involves cognitive work--the engineering complement to socio-technical systems.
- Human is in the system, not apart from it
- Reflects evolution of intelligent systems and complex, dynamic human-machine interaction
- Relies on problem-driven, instead a technology-driven, approach
- Trends away from traditional function allocation ("leave the hard stuff to the operator") into dynamic adaptive systems (meet challenge with best capabilities).
- Contributes to system resilience—ability to adapt to unforeseen challenge.

Hollnagel, E. and Woods, D. (2005) Joint Cognitive Systems: Foundations of Cognitive Systems Engineering. Taylor and Francis/CRC Press: Boca Raton, FL.
Nemeth, C. (2009). The Ability to Adapt. In C. Nemeth, E. Hollnagel, E and S. Dekker (Eds.). *Preparation and Restoration*. Resilience Engineering Perspectives. 2. Farnham, UK: Ashgate Publishing.

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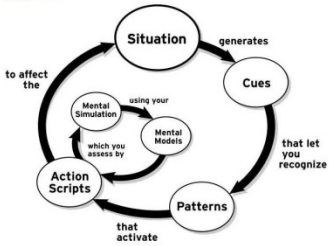
Model: Recognition Primed Decision Making

- Recognition-Primed Decision-Making (RPD) Model explains how people develop expectations that guide attention to cues, use mental simulation to try out solutions, commit to action
- Experience allows people to form a repertoire of patterns, and a sense of the patterns that are typically present in a given situation.
- Patterns highlight the most relevant cues in a situation, provide notions of what to expect, identify plausible goals, and suggest typical types of reactions.



Klein, GA. Recognition-primed decisions. Pp. 47-92 in WB Rouse ed. Advances in man-machine systems research. Vol. 5. 1989. JAI Press, Greenwich, CT.

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Method: Cognitive Systems Engineering

- Rigorous triangulated field data collection : observations, structured interviews, artifact analysis
- Thorough analyses that drive decision requirements and design requirements
- Solutions based on those requirements
- Evaluation based on performance criteria developed during data collection and analysis

Typical CSE Process

Field research data lead to

↓

Operator descriptive cognitive models, to

↓

Decision and information requirements, to

↓

Prototype solutions to be evaluated and optimized

Woods D, and Roth E. (1988). Cognitive Systems Engineering. In Helander M. (Ed.) *Handbook of Human-Computer Interaction*. (pp. 3-43). Amsterdam: North-Holland.
Crandall, B, Klein, G, and Hoffman. Working Minds: A Practitioner's Guide to Cognitive Task Analysis. 2006. The MIT Press, Cambridge, MA.

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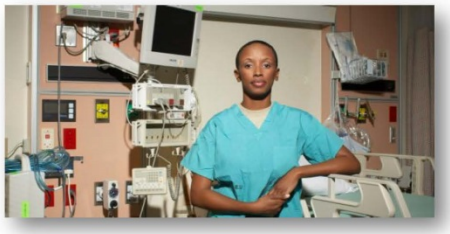
Research Site

- Burn ICU in tertiary care medical center,
- 16 beds, 2 reserved to serve as a post-anesthesia care unit (PACU), 1 dedicated to support Extracorporeal Membrane Oxygenation (ECMO).
- Other nearby units support the ICU, including a step down unit, burn operating room, and outpatient clinic.
- Population averages around 8 patients but as high as 13
- Patients have severe affliction from chemical, mechanical or electrical burns, or burn-like afflictions such as toxic epidermal necrolysis (TENS).
- Length of stay ranges from days to months.



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Research Design

- Goal is to improve care by better supporting the judgment of individuals and teams who care for patients through a cognitive aid that also assists communication.
- Three phases that are scheduled to take roughly a year apiece: foundation research, cognitive aid prototype development, and prototype assessment.

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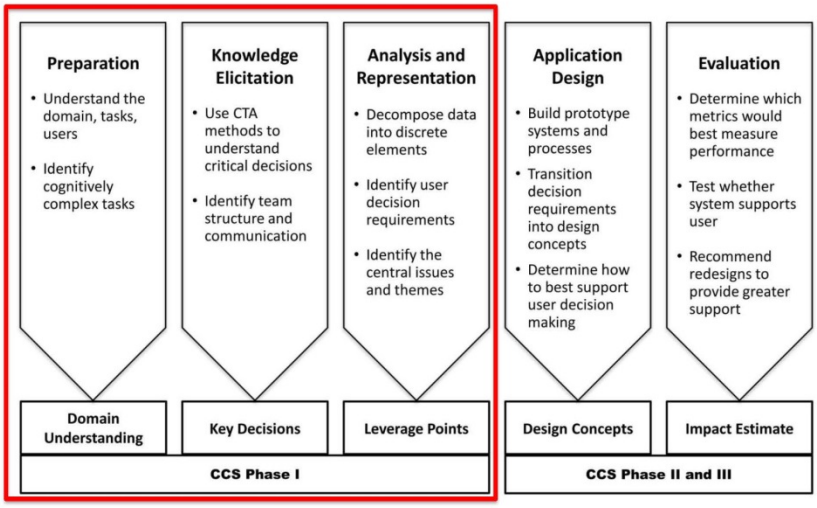
Cognitive Systems Engineering Phase 1



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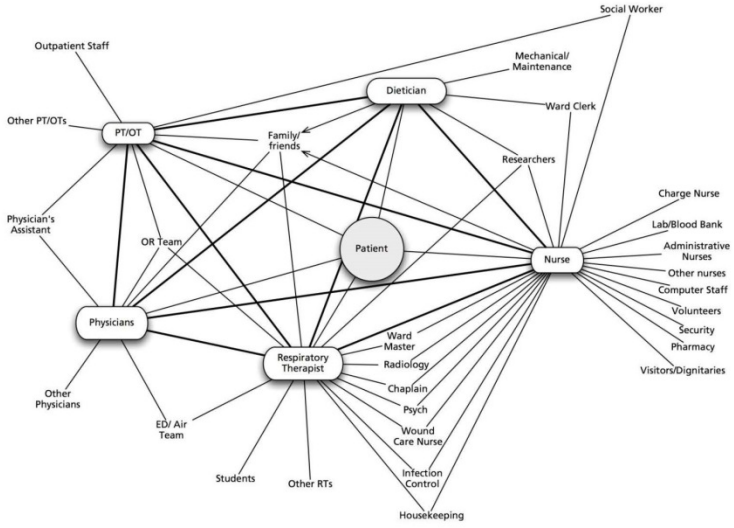
BICU Patient Team



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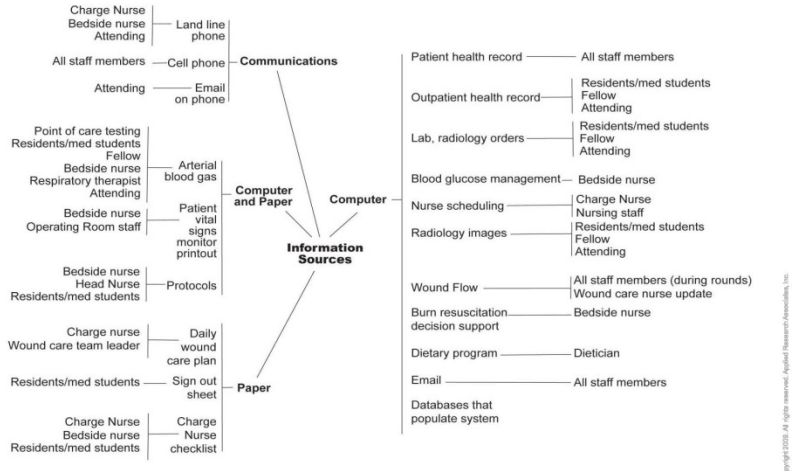
BICU Information Sources



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BICU Cognitive Model

Function Unit Members Perform	*Activities Unit Members Perform*	*Tasks Unit Members Perform*
Synchronization	**Clarification**	Reduce uncertainty Manage ambiguity Manage conflicting agendas Manage communication
	Coordination	Develop shared awareness of the Patient Get and keep common ground Manage the care plan and treatment goals Coordinate resources
	Negotiation	Identify alignment, gaps/differences (e.g., agendas) Manage conflicting agendas Manage communication
	Anticipation	Forward thinking

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Barrier

No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.

Requirement

System shall provide access to a plan of patient care, visible to all care givers responsible for that patient that includes:

- *Current patient status and top-level assessment*
- *Goals and priorities for those goals*
- *Changes/updates, such as indication that plan is being updated when one caregiver is working on it*
- *Schedule of activities and any changes, timeline*
- *Orders and their status*
- *Identity and contact information for patient's care team*

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Use Case

"At 0630, a bedside nurse has started his preparation for the day ***shift*** *by reviewing information on the patient he is responsible for. Opening CCS, he can see a* ***roster of patients on the unit****, chooses his patient's* ***"at-a-glance" view*** *that shows* ***recent vital signs, current orders, medications, care plan,*** *and* ***notes from the night shift****. He checks the patient's standing* ***care plan*** *and* ***treatment goals*** *(from the electronic healthcare record), and* ***reviews orders*** *(from the laboratory test database) that are pending as well as the day's* ***care activities that the Wound Care team, Respiratory Therapists, and Physical Therapists*** *have recommended and* ***what times*** *they can perform them…"*

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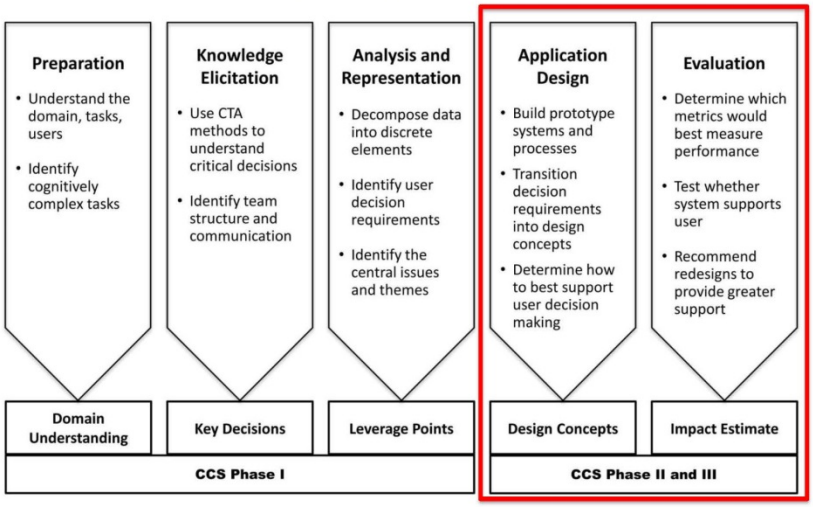
Cognitive Systems Engineering Phases Two, Three



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Patient View

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Clinician-Specific View: RT

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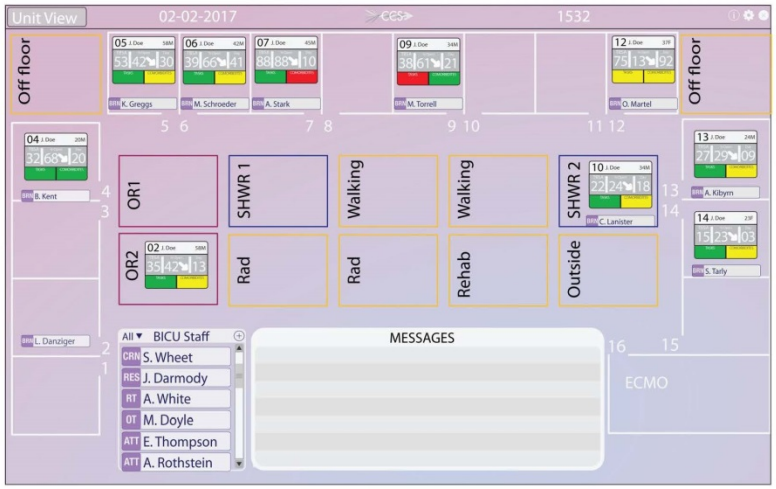
Unit View



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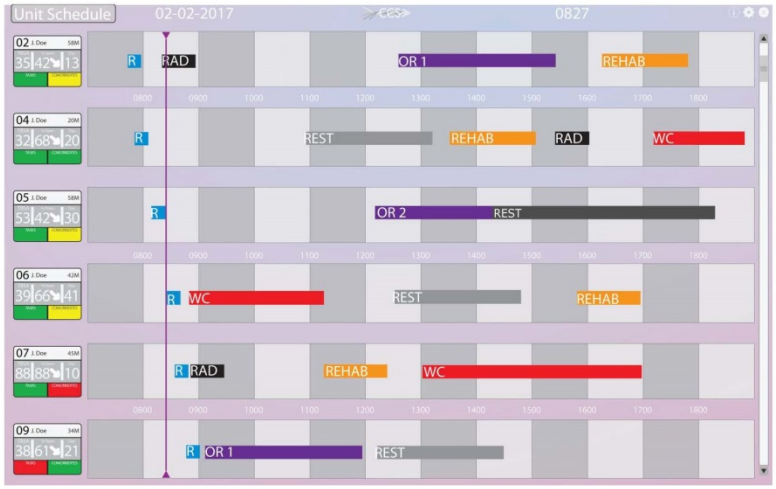
Unit View: Schedule



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Revealing Inter-dependencies

Phenotype: *Clinicians talk among each other, spend a good deal of time writing at terminals* ***Work-around***

Genotype: *Disconnected databases*

Source of brittleness

Barrier: *No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.*

Blocks synchronization

Requirement: *System shall provide access to a plan of patient care, visible to all care givers responsible for that patient*

Source of resilience

Features:

- *Current patient status and top-level assessment*
- *Goals and goal priorities*
- *Changes/updates, such as indication that plan is being updated when one caregiver is working on it*
- *Schedule of activities and any changes, timeline*
- *Orders and their status*
- *Patient's care team identity and contact information*

Facilitates synchronization

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Resilience

Three characteristics that CSE can assist:

- *Being self-aware*--Disconnection among specialties is aggravated by disconnected information sources.
- *Able to identify and apply resources*--Scheduling is currently done using hard copy forms and in-person negotiation, which makes it difficult to develop and maintain an optimal plan.
- *Able to adapt to surprise*--Use of CSE makes understanding what goes right, and what occasionally does not, a routine learning process that can improve the ability to adapt.

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Next Steps

- Develop a prototype compatible with IT requirements
- Test and validate the prototype in concert with other IT solutions that are currently in use
- Field in a clinical setting

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Your comments and correspondence are welcome.

谢谢！

Christopher Nemeth, PhD
cnemeth@ara.com

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Appendix O. Nemeth, C. Invited presenter: *The Human Factor in Engineered Systems*. Faculty of Science and Technology, University of Macau. Macau, SAR, China. April 2015.

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The Human Factor in Engineered Systems

Cognitive Systems Engineering

Christopher Nemeth, PhD, CHFP

University of Macau

2 April 2015

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Brief Introduction

- University of Chicago Medical Center Department of Anesthesiology and Critical Care
- Cognitive Solutions Division, Applied Research Associates

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2

What I Will Discuss Today

- Theory: Human Factors, Joint Cognitive Systems
- Model: Recognition Primed Decision Making
- Method: Cognitive Systems Engineering (CSE)
- Examples of CSE
- Human-Centered Research Design
- IT Design Case Study: Acute Care Artifact Analysis

3

Human Factors in High Risk Work Domains

- Human factors applies knowledge of physiology and psychology to create human-centered solutions from work processes to controls and displays, and facilities to assure safe, efficient, resilient performance.
- Aviation/aerospace, military, high speed ground transportation, nuclear power generation, healthcare
- Time-pressured, complex, resource-constrained, poorly bounded, uncertain, evanescent. No single person's knowledge is adequate. Stakes are high.
- Healthcare is a good example I'll use today

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Joint Cognitive Systems

- Assembly of elements intended to accomplish a desired goal that involves cognitive work--the engineering complement to socio-technical systems.
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- Relies on problem-driven, instead a technology-driven, approach
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Recognition Primed Decision Making

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- Experience allows people to form a repertoire of patterns, and a sense of the patterns that are typically present in a given situation.
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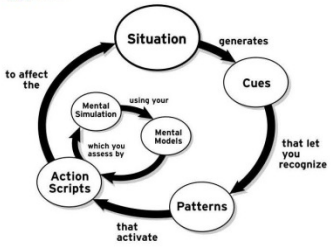

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Cognitive Systems Engineering

- Rigorous triangulated field data collection : observations, structured interviews, artifact analysis
- Thorough analyses that drive decision requirements and design requirements
- Solutions based on those requirements
- Evaluation based on performance criteria developed during data collection and analysis

Typical CSE Process

Field research data lead to

↓

Operator descriptive cognitive models, to

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Decision and information requirements, to

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Prototype solutions to be evaluated and optimized

Woods D, and Roth E. (1988). Cognitive Systems Engineering. In Helander M. (Ed.) *Handbook of Human-Computer Interaction*. (pp. 3-43). Amsterdam: North-Holland.
Crandall, B, Klein, G, and Hoffman. Working Minds: A Practitioner's Guide to Cognitive Task Analysis. 2006. The MIT Press, Cambridge, MA.

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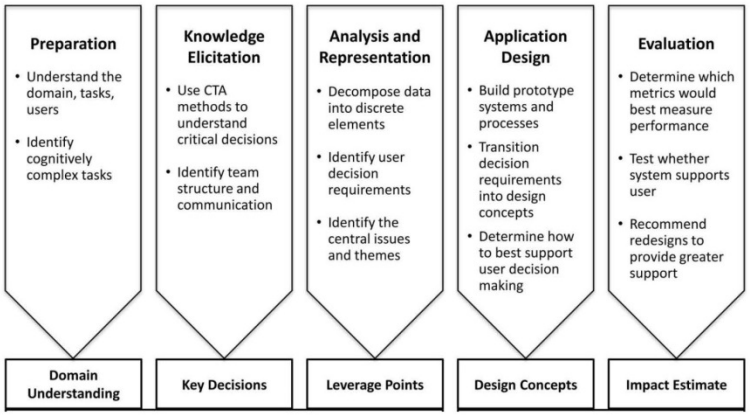
How Do We Know?



Five phases of Cognitive Systems Engineering source: Crandall, Klein & Hoffman, 2006).

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Key Points

Methods enable us to understand work domain and operator behavior

- Cognitive systems engineering methods , including artifact analysis, offer a "way in" at the right level
- Controlled studies and field studies inform each other

Cognitive work in high risk domains

- Uncertainty drives high risk domains, including healthcare
- Complexity of cognitive work matches the work domain
- Workers need tools that are as sophisticated as their strategies

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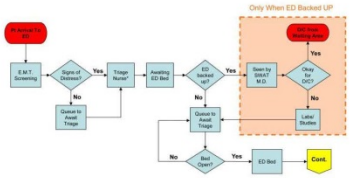
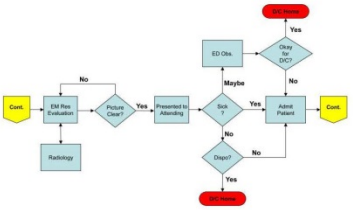
Some Examples

Is this is the ED?

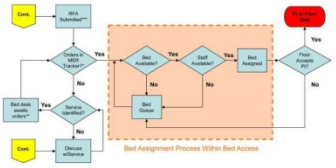
Waiting Flow



Evaluation Flow



Admission Flow



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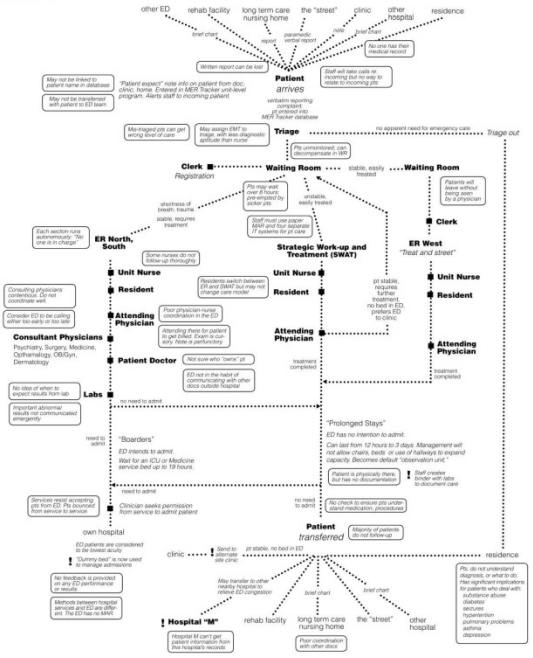
Is *this* is the ED?



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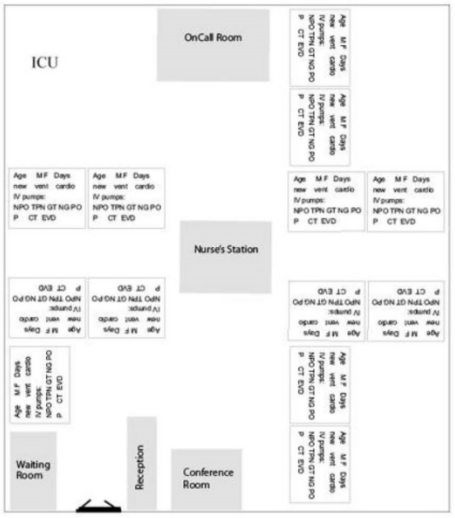
Some Examples

Is this is the ICU?



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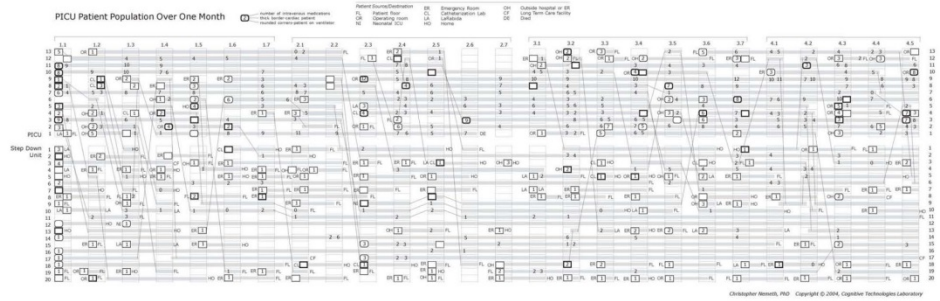
Is *this* is the ICU?



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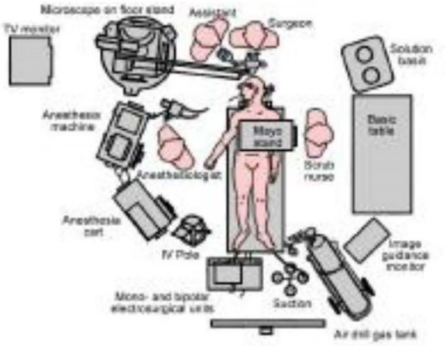
Some Examples

Is this is the OR?



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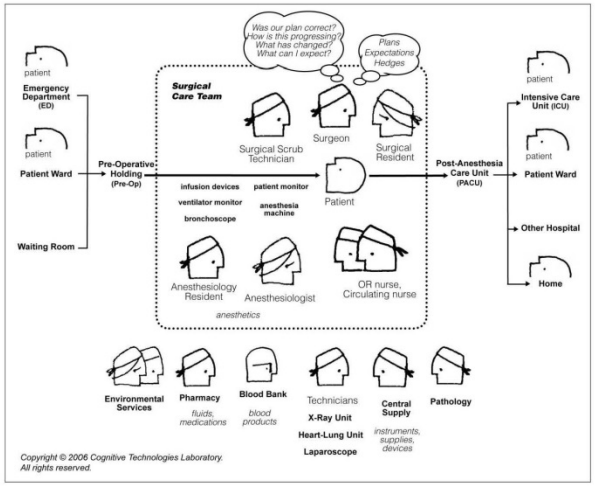
Is *this* is the OR?



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Pop Quiz!

Q. What is this equation?

$$A_{jk} = \sum_{i=1}^{n} I_{ik} B_{ijk}$$

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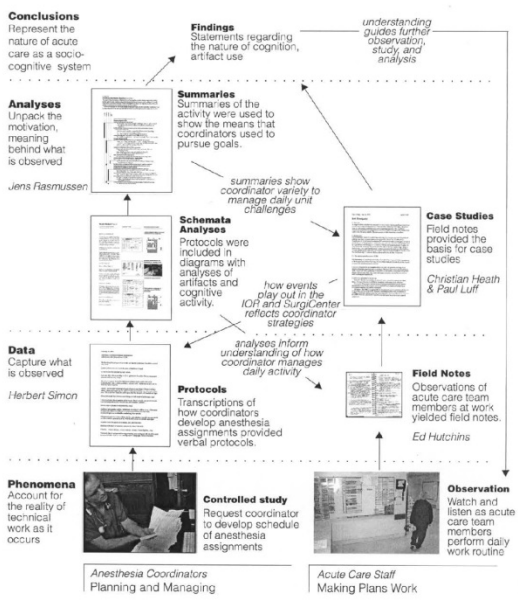
How Does It Work?

Analyze
Schedule strategy, implications

Schedule creation cognition

Document
Schedule creation, Availabilities use

Schedule creation using availabilities



Analyze
Master schedule, OR Board use

Document
Master schedule, OR board use

Master schedule, OR board use

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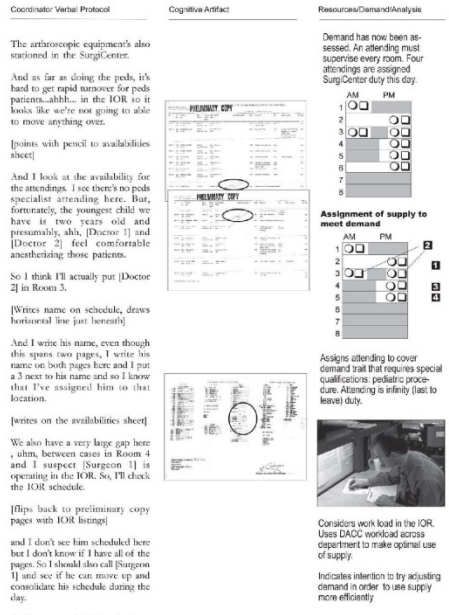
Coordinator Plan



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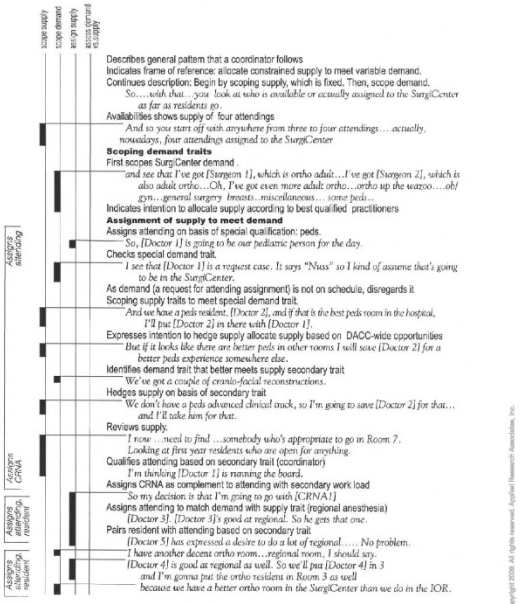
Match supply to demand



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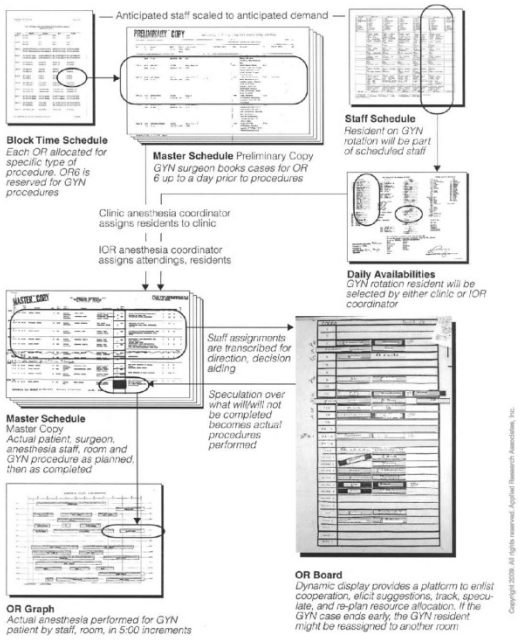
OR Scheduling Cognitive Artifacts

Local
Coordinators

Public
Acute care team

Local
Billing



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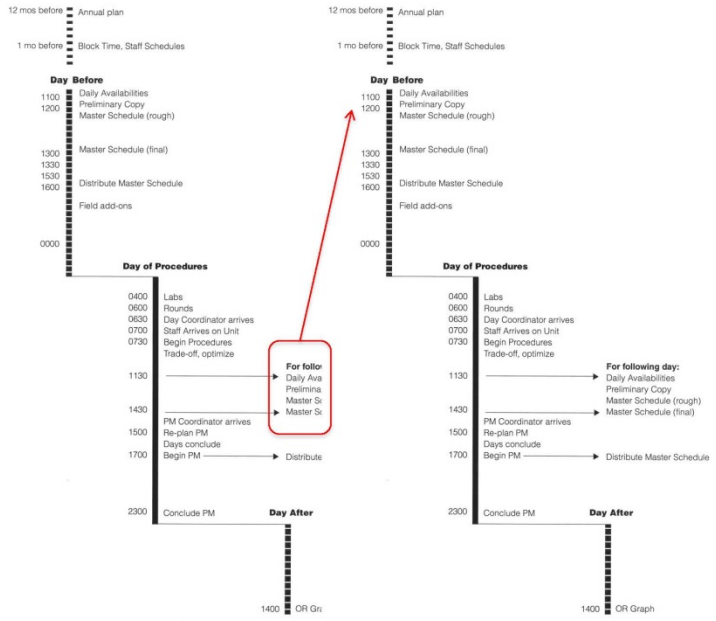
Timeline



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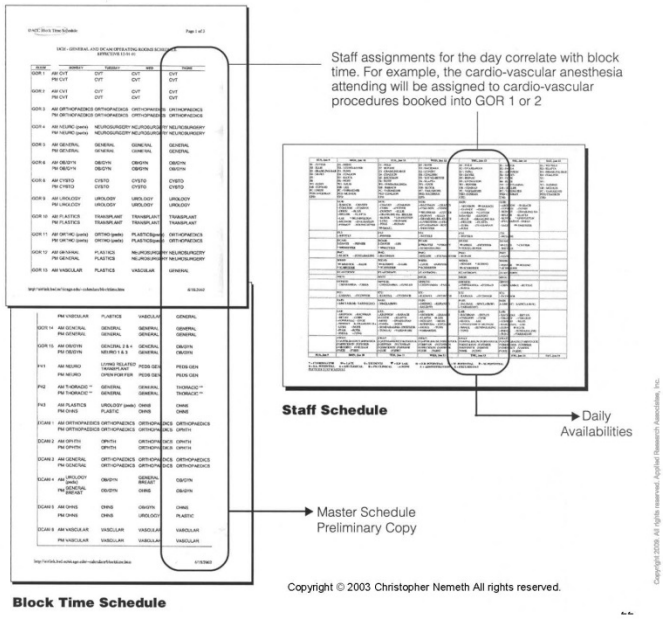
Block, Staff Schedules



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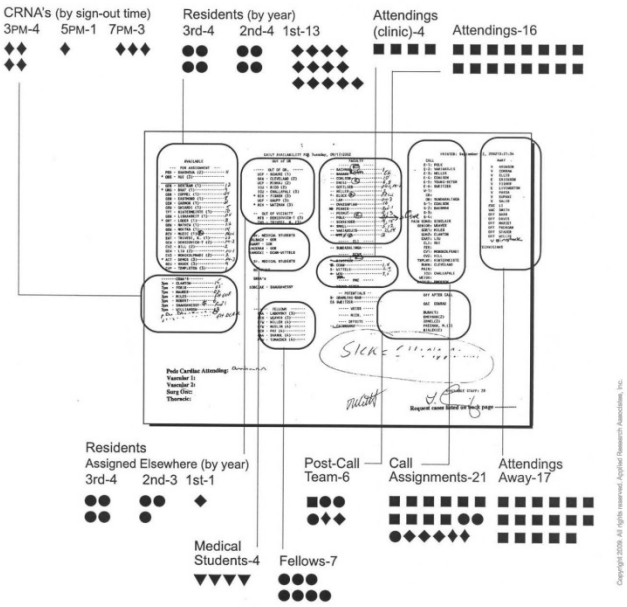
Daily Availabilities



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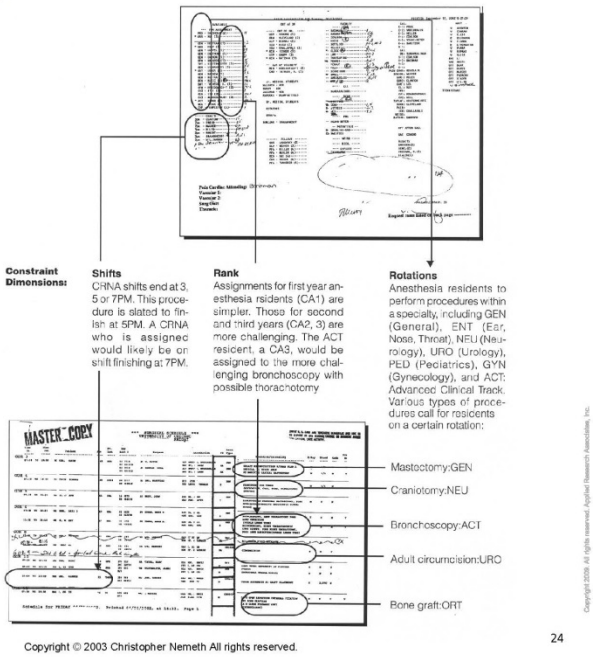
Daily Availabilities



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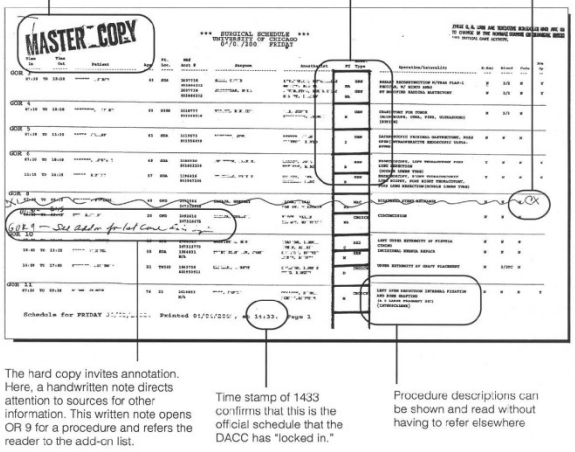
Master Schedule

Only one hard copy receives this stamp in purple ink. It becomes the sole representation of the unit's status through the day

The "anesthesia type" column provides a site to indicate patient status. The blank dedicated field implies unmet demand and invites the attention of unit members, the supply, regarding how needs will be balanced.

Cases that have been cancelled ("cx") remain on the hard copy, making it possible to trace how the day's events evolved.



The hard copy invites annotation. Here, a handwritten note directs attention to sources for other information. This written note opens OR 9 for a procedure and refers the reader to the add-on list.

Time stamp of 1433 confirms that this is the official schedule that the DACC has "locked in."

Procedure descriptions can be shown and read without having to refer elsewhere

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Master Schedule

Master Schedule as of 0630

Master Schedule as of 1700

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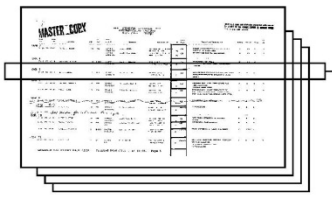

time

PACU Determine workload, staff needs
Technicians Which tools, equipment to prepare
Pathology How many frozen sections to expect
Radiology Fluroscopes and technicians needed
Microbiology Determine workload, staff needs
NC Make nurse assignments
Transporters Anticipate (w/Pre-op RN) assignments
Pharmacy Prepare medications
NC Verify OR room is open
NC Request in-patient transport to Pre-op

Patient (ambulatory) Arrive in waiting room
Patient Arrive in Pre-op
PACU Report Patient in Pre-op
Pre-op RN Consent, NPO, paperwork
OR RN Verify patient ID, consent, laterality, procedure
NC Confirm Patient in OR Room

OR RN Report start of procedure
NC Confirm procedure start
OR RN, med students Prepare patient

Radiology Provide services as needed
Pathology Provide services as needed
OR RN Calls report to PACU
PACU Prepare for patient

NC Confirm patient transfer
Housekeeping Clean OR
Technicians Remove, clean tools, equipment
OR RN Set up for next case

AC Post anesthesia assignments

AC Review case load and anesthesia assignments
Anesthesia attendings, residents, CRNAs Check assignments

Anesthesia resident/CRNA Set up room

Surgery resident Verify NPO, consent, laterality, H+P. Write orders, X-ray, labs, and path forms
Anesthesia resident/CRNA Verify NPO, consent. Start IV
Anesthesia, surgery attendings Visit patient in pre-op
Anesthesia resident/CRNA Approve patient to proceed
Patient Transfer to OR
Patient Transfer to OR table
Anesthesia attending Induce anesthesia, supervise resident/CRNA

Surgery attending Start procedure
AC Patrol IOR to check each OR's progress, offer breaks
Anesthesia resident/CRNA Call for next patient
Anesthesia resident/CRNA Report to OR RN

Surgery resident Finish procedure
Anesthesia resident/CRNA Conclude anesthesia
Patient Awaken
Patient Transport to PACU
Anesthesia resident/CRNA Report patient transfer to AC, NC
Anesthesia resident/CRNA Turn OR over for next case

Billing Actual procedure, expense

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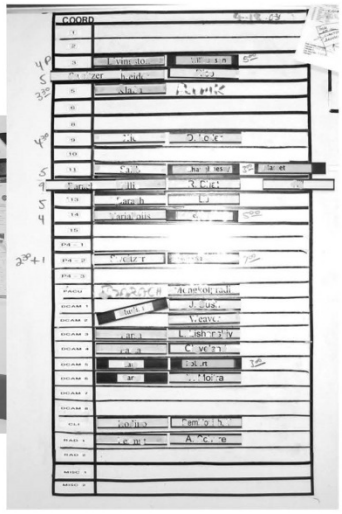
OR Board



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Pop Quiz!

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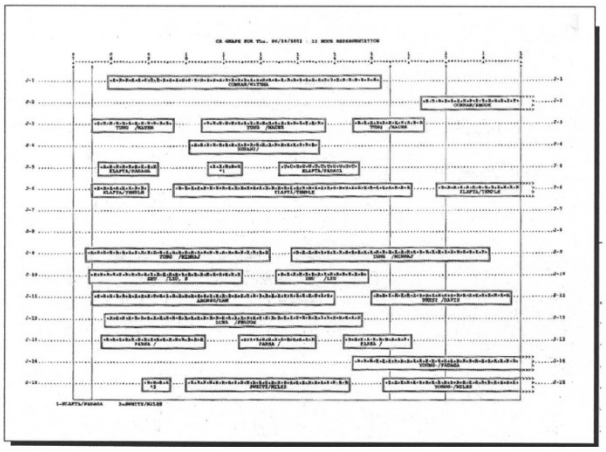
OR Graph



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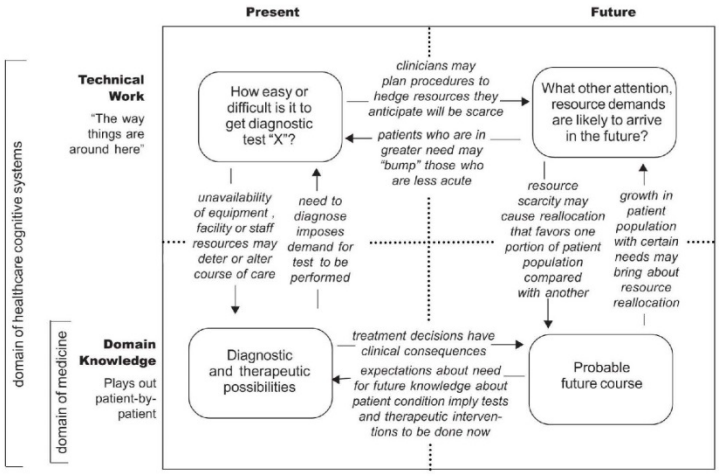
What Does This Mean for IT Development?



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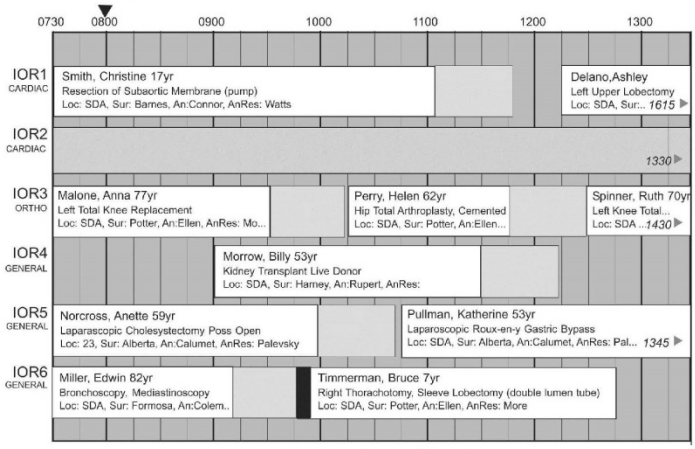
Solution Prototype



Nemeth C.P. & Cook R.I. (2004, June). Discovering and Supporting Temporal Cognition in Complex Environments. *Proceedings of the Twenty-Sixth Annual Conference of the Cognitive Science Society*. Chicago, IL: Lawrence Erlbaum Associates. 1005-10.

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Your comments and questions are welcome:

谢谢！

Christopher Nemeth, PhD, CHFP
cnemeth@ara.com

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Appendix P. Updated CCS Prototype – Configurable Patient View

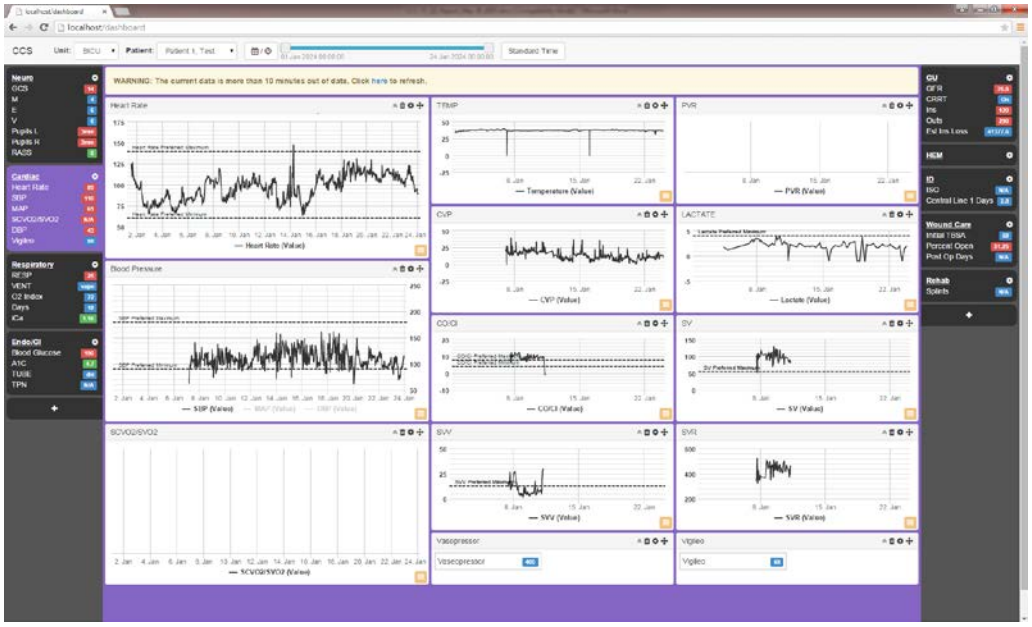


Figure P-1. Configurable Patient View.

Appendix Q. Poster Presented by Dr. Chris Nemeth at the Human Factors and Ergonomics Society (HFES) Healthcare Symposium. Baltimore, Maryland. April 2015.

Developing a Cognitive and Communications Tool for Burn ICU Clinicians

Christopher Nemeth1, Jeremy Pamplin2, Shilo Anders1, Anna Grome1, Robert Strouse1, Beth Crandall1, Jose Salinas2, Elizabeth Mann-Salinas2

1. Applied Research Associates, Inc.; 2 United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX

Background

Burn intensive care unit (BICU) work is necessarily complex and depends on clinician actions, resources, and variable patient responses to interventions. Clinicians use large volumes of data condensed in time but separated across resources to care for patients. Correctly designed health information technology (IT) systems may help clinicians to treat these patients more efficiently, accurately, and reliably. We are in the second year of a 3-year project to design and develop an ecologically valid IT system for use in a military BICU.

Objectives

Develop a real-time decision support & communications system for tertiary care hospital Burn Intensive Care Unit.

Methods

We have used a mixed methods Cognitive Systems Engineering (CSE) approach (observations, interviews, artifact analysis, surveys) to go beyond surface descriptions (phenotypes) and reveal underlying patterns (genotypes) of systemic factors that mold the work environment and affect clinician decisions. Data analyses further identified clinician goals and barriers to goal achievement. The team made 4 week-long data collection visits to the research site, and coordinated additional collection with an onsite research nurse between visits. Methods included:

a. **Observation** of clinical teams providing patient care and managing the unit. Team members conducted 31 observations with the Burn ICU staff, including bedside, charge and wound care nurses, residents, attending physicians, and physical, occupational, and respiratory therapists. Observation included shadowing an individual and asking them to talk aloud as they completed their work. Probe questions enabled researchers to request background and clarifying information in context to better understand motivations, information use, and decision making.

b. **Cognitive Task Analysis**. Forty-nine semi-structured interviews from 30 to 90 minutes with Burn ICU clinical staff elicited knowledge about their background, perspectives, work activity, information sources, and challenges they face.

c. **Analysis** of computer-based and hard copy information sources that clinicians use in their work, including sign-out sheets, personal notes, status boards, and information system and equipment displays.

d. **Brief surveys** identified patterns, such as work team relationships.

Data Analysis

Through 8 steps, the team analyzed data collected from 4 week-long site visits and on-site research nurse support.

a. Initial data review and extraction of emerging themes to review and analyze interview, observation notes from each visit.

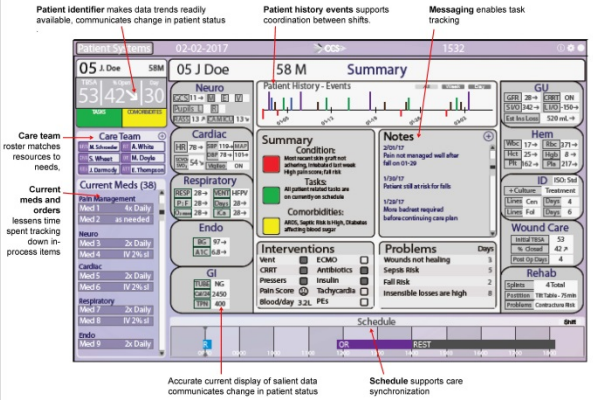
b. Systematic data review and coding to both reveal thematic categories developed during working sessions, and to code interview sections to relate them to each theme.

c. Review and interpretation of coded data.

d. Findings synthesis and integration, and reflection on newly-collected data.

e. Development of initial requirements for the system, following synthesis.

The Patient Systems View Information Design Prototype



f. Preliminary validation of findings to present the challenges/barriers and initial requirements to a select set of BICU clinicians. Obtained an initial appraisal of the findings by verifying accuracy and identifying possible gaps.

g. Analysis of cognitive work to provide the basis for analyzing the cognitive work requirements of Burn ICU clinical teams and distill a descriptive model.

h. Analysis of the forms and other cognitive artifacts that the Burn ICU clinical teams use, in order to more fully understand the kinds of information they seek, use, and share with one another.

Ideas/suggestions

Clinician patient care decisions are based on information that is provided by various means, which increasingly include the electronic health record (EHR). While providing some benefits, the EHR's rapid development has created "…digital piles grown so gigantic, unwieldy and unreadable that sometimes we wind up working with no information at all" [Zuger A. Repeating the mistakes of history. New York Times; 2014 Oct 14:D1,6]. The inability to identify key data can divert attention, delay decisions, or induce errors. Cognitive systems engineering methods can improve the visibility of data that are most useful to decision making. Machine learning features can be used sort through the "digital" piles to make useful information salient (stands out, or is prominent).

Takeaways

Despite years of effort in medical informatics, a gulf remains between clinical work setting complexities and the information systems that are intended to support clinician cognitive work.

Healthcare IT systems must reflect actual clinical practice in order to provide information that will effectively support decision making and related cognitive work of patient care. The ability to defend an IT design proposal relies on evidence that it is based on actual needs in the work domain, and that the design improves clinician performance. The use of CSE to produce ecologically valid IT systems is expected to increase staff efficiency and the quality of patient care they can provide by improving information salience, as well as clinician decision making and communication.

Results

The data analysis process identified 21 key challenges and barriers to cognitive work on the Burn ICU. Using the challenges and barriers, the team created a set of problem statements, then developed 39 concise statements of system requirements. We used the requirements to create 3 use cases in order to help developers better understand how the system might support clinician work. We developed a series of information design prototypes based on the requirements.

After translating analysis findings into concise problem statements and information system requirements, the team developed a number of representations to describe the BICU environment and key information resources. We developed diagrams to describe the unit, its work and interactions. These included a model of cognitive work, an inventory of information sources that clinicians use, and a network of key patient care providers. The network enabled us to select which of the system views we would develop in the first version of the prototype.

We are developing interface prototypes that incorporate data mining functions, including three main views:

a. **Patient**—Critical variables are shown for each patient organized by neural, cardiac, respiratory, gastrointestinal, pulmonary, and renal systems. A "parent-child" display tab feature serves as a kind of tab reference to see more detailed material. The view also includes a analysis of the patient's skin and graft condition (developed by the research site), as well as the patient's schedule for the day.

b. **Rounds**—Provides a means for the Charge Nurse to document key details of the daily interdisciplinary rounds that are conducted each morning starting at 0800. Entry of goals, medications, and orders captures patient care decisions, put them in motion, and makes it possible to track their progress through the day

c. **Unit**—Indicates the location and condition for each of the patients in the 16-bed unit, along with the two adjacent operating rooms.

We will evaluate the prototype with BICU clinicians to develop rough, then increasingly improved, designs. The system will be tested in a laboratory setting against current DoD standards and requirements the team has developed.

Implications

The link from data to analyses, requirements, prototypes, and evaluation ensures that the solution will reflect and support work in the BICU as it actually occurs.

Rigorous use of proven methods is essential for the development of a system that will be considered for use in a complex clinical care setting.

Acknowledgements

We thank Dianne Hancock, Greg Rule, and Nicole Caldwell for their help to make this project possible.

This work is supported by the US Army Medical Research and Materiel Command under Contract No.W81XWH-12-C-0126. The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation. In the conduct of research where humans are the subjects, the investigator(s) adhered to the policies regarding the protection of human subjects as prescribed by Code of Federal Regulations (CFR) Title 45, Volume 1, Part 46; Title 32, Chapter 1, Part 219; and Title 21, Chapter 1, Part 50 (Protection of Human Subjects).

Appendix R. Presentation by Dr. Christopher Nemeth at the Department of Defense Human Factors Engineering Technical Advisory Group Meeting: ***The Role of CSE in Individual and Team ICU Decision Making.***

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The Role of CSE in Individual and Team ICU Decision Making

Presented by
Christopher Nemeth, PhD, CHFP
To
Department of Defense Human Factors Engineering
Technical Advisory Group Meeting 69
Date
6 May 2015

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Objectives for This Session

- Understand how human factors can help to improve healthcare reliability, safety, efficiency, and resilience.
- Understand how use of CSE can improve resilience, using healthcare as an example
- Apply use of CSE to IT development, training

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Human Factors in High Risk Work Domains

- Human factors applies knowledge of physiology and psychology to create human-centered solutions from work processes to controls and displays, and facilities to assure safe, efficient, resilient performance.
- Aviation/aerospace, military, high speed ground transportation, nuclear power generation, healthcare
- Time-pressured, complex, resource-constrained, poorly bounded, uncertain, evanescent. No single person's knowledge is adequate. Stakes are high.
- Healthcare is a good example I'll use today

Nemeth, C. (2004). *Human Factors Methods for Design*. Boca Raton, FL: Taylor and Francis/CRC Press

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Theory: Joint Cognitive Systems

- Assembly of elements intended to accomplish a desired goal that involves cognitive work--the engineering complement to socio-technical systems.
- Human is in the system, not apart from it
- Reflects evolution of intelligent systems and complex, dynamic human-machine interaction
- Relies on problem-driven, instead a technology-driven, approach
- Trends away from traditional function allocation ("leave the hard stuff to the operator") into dynamic adaptive systems (meet challenge with best capabilities).
- Contributes to system resilience—ability to adapt to unforeseen challenge.

Hollnagel, E. and Woods, D. (2005) Joint Cognitive Systems: Foundations of Cognitive Systems Engineering. Taylor and Francis/CRC Press: Boca Raton, FL.
Nemeth, C. (2009). The Ability to Adapt. In C. Nemeth, E. Hollnagel, E and S. Dekker (Eds.). *Preparation and Restoration*. Resilience Engineering Perspectives. 2. Farnham, UK: Ashgate Publishing.

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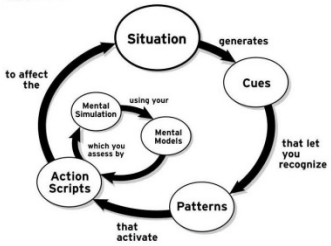
Model: Recognition Primed Decision Making

- Recognition-Primed Decision-Making (RPD) Model explains how people develop expectations that guide attention to cues, use mental simulation to try out solutions, commit to action
- Experience allows people to form a repertoire of patterns, and a sense of the patterns that are typically present in a given situation.
- Patterns highlight the most relevant cues in a situation, provide notions of what to expect, identify plausible goals, and suggest typical types of reactions.



Klein, GA. Recognition-primed decisions. Pp. 47-92 in WB Rouse ed. Advances in man-machine systems research. Vol. 5. 1989. JAI Press, Greenwich, CT.

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Method: Cognitive Systems Engineering

- Rigorous triangulated field data collection : observations, structured interviews, artifact analysis
- Thorough analyses that drive decision requirements and design requirements
- Solutions based on those requirements
- Evaluation based on performance criteria developed during data collection and analysis

Typical CSE Process

Field research data lead to

↓

Operator descriptive cognitive models, to

↓

Decision and information requirements, to

↓

Prototype solutions to be evaluated and optimized

Woods D, and Roth E. (1988). Cognitive Systems Engineering. In Helander M. (Ed.) *Handbook of Human-Computer Interaction*. (pp. 3-43). Amsterdam: North-Holland.

Crandall, B, Klein, G, and Hoffman. Working Minds: A Practitioner's Guide to Cognitive Task Analysis. 2006. The MIT Press, Cambridge, MA.

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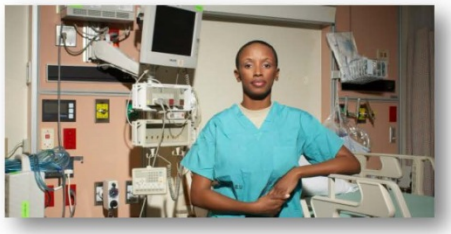
Research Site

- Burn ICU in tertiary care medical center,
- 16 beds, 2 reserved to serve as a post-anesthesia care unit (PACU), 1 dedicated to support Extracorporeal Membrane Oxygenation (ECMO).
- Other nearby units support the ICU, including a step down unit, burn operating room, and outpatient clinic.
- Population averages around 8 patients but as high as 13
- Patients have severe affliction from chemical, mechanical or electrical burns, or burn-like afflictions such as toxic epidermal necrolysis (TENS).
- Length of stay ranges from days to months.



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IBM PC
Week of training

Apple Macintosh
No training

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Research Design

- Goal is to improve care by better supporting the judgment of individuals and teams who care for patients through a cognitive aid that also assists communication.
- Three phases that are scheduled to take roughly a year apiece: foundation research, cognitive aid prototype development, and prototype assessment.

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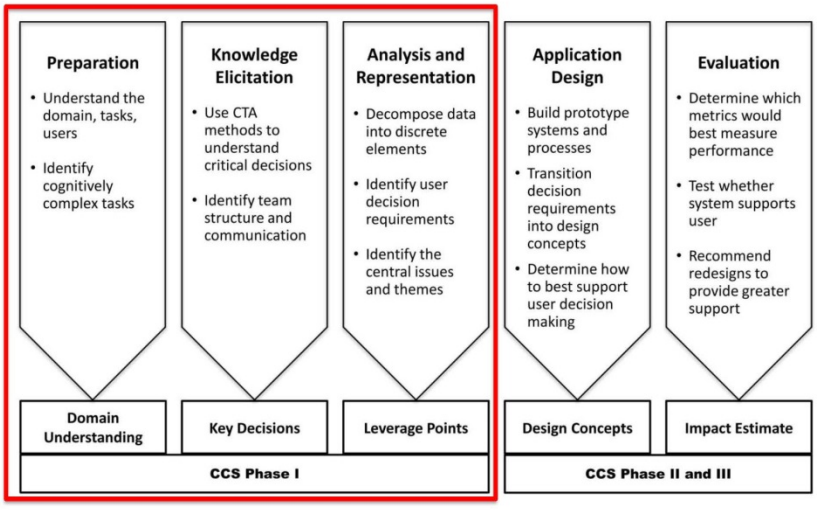
Cognitive Systems Engineering Phase 1



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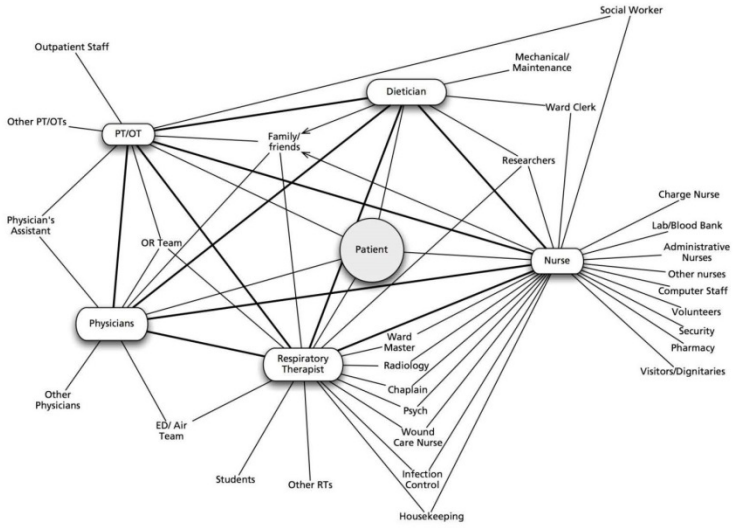
BICU Patient Team



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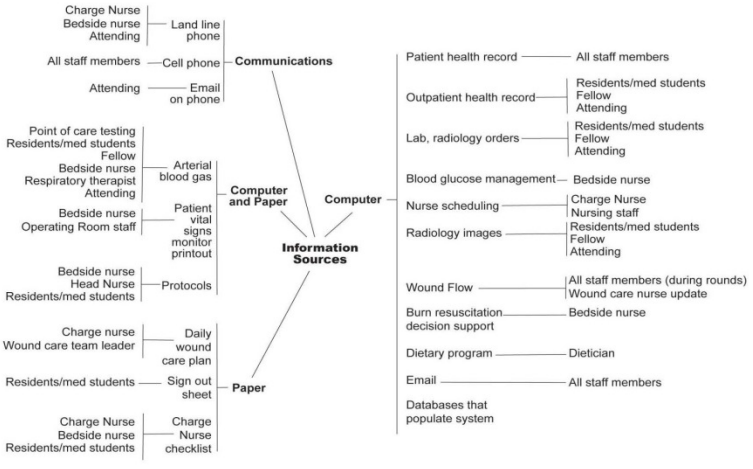
BICU Information Sources



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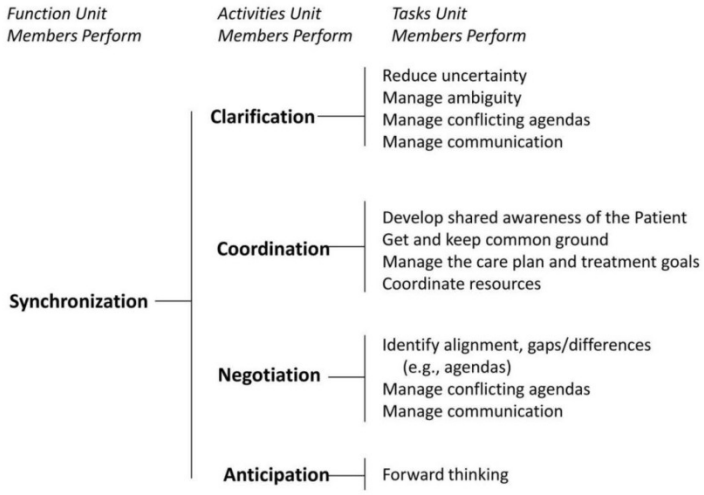
BICU Cognitive Model



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Barrier

No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.

Requirement

System shall provide access to a plan of patient care, visible to all care givers responsible for that patient that includes:

- *Current patient status and top-level assessment*
- *Goals and priorities for those goals*
- *Changes/updates, such as indication that plan is being updated when one caregiver is working on it*
- *Schedule of activities and any changes, timeline*
- *Orders and their status*
- *Identity and contact information for patient's care team*

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Use Case

"At 0630, a bedside nurse has started his preparation for the day ***shift*** *by reviewing information on the patient he is responsible for. Opening CCS, he can see a* ***roster of patients on the unit****, chooses his patient's* ***"at-a-glance" view*** *that shows* ***recent vital signs, current orders, medications, care plan,*** *and* ***notes from the night shift****. He checks the patient's standing* ***care plan*** *and* ***treatment goals*** *(from the electronic healthcare record), and* ***reviews orders*** *(from the laboratory test database) that are pending as well as the day's* ***care activities that the Wound Care team, Respiratory Therapists, and Physical Therapists*** *have recommended and* ***what times*** *they can perform them…"*

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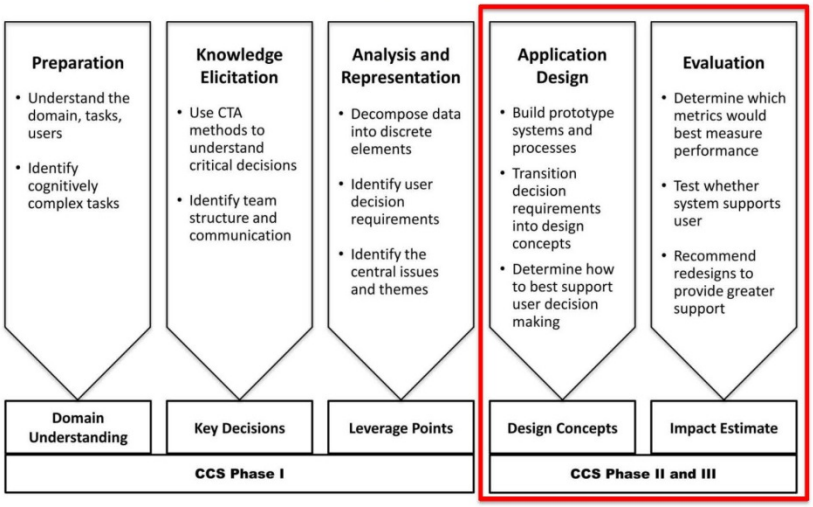
Cognitive Systems Engineering Phases Two, Three



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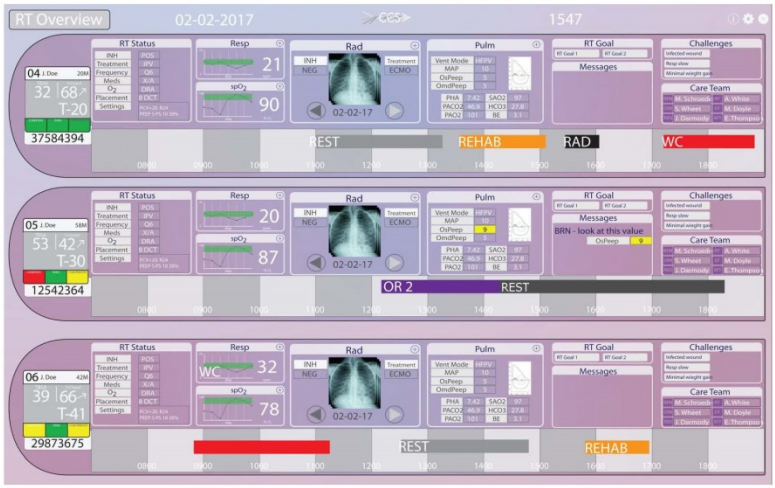
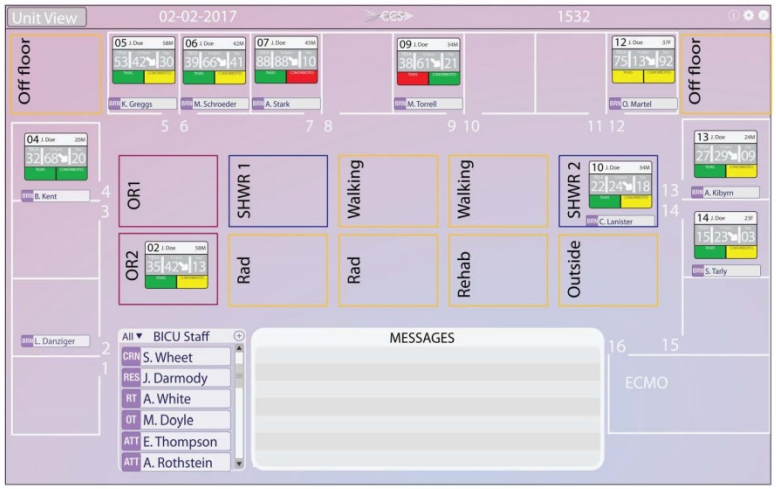
Patient View

Clinician-Specific View: RT



Unit View



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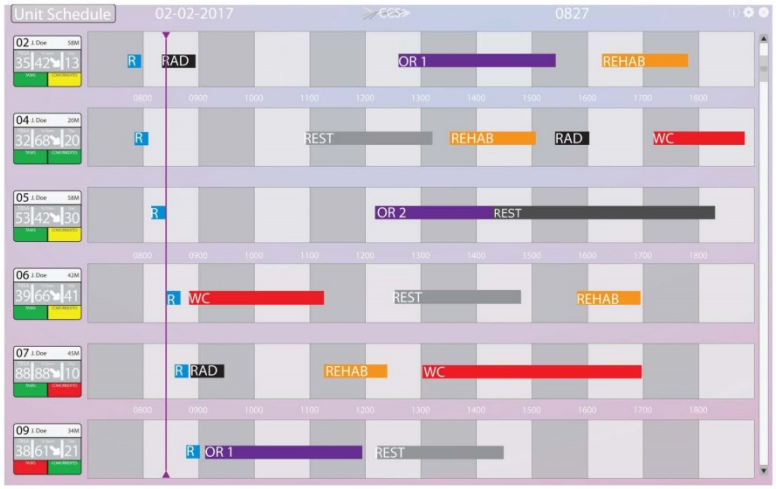
Unit View: Schedule



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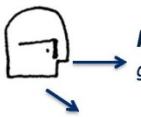
Revealing Inter-dependencies



Phenotype: *Clinicians talk among each other, spend a good deal of time writing at terminals* ***Work-around***

Genotype: *Disconnected databases*

Source of brittleness

Barrier: *No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.*

Blocks synchronization

Requirement: *System shall provide access to a plan of patient care, visible to all care givers responsible for that patient*

Source of resilience

Features:

Current patient status and top-level assessment
Goals and goal priorities
Changes/updates, such as indication that plan is being updated when one caregiver is working on it
Schedule of activities and any changes, timeline
Orders and their status
Patient's care team identity and contact information

Facilitates synchronization

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Resilience

Three characteristics that CSE can assist:

- *Being self-aware*--Disconnection among specialties is aggravated by disconnected information sources.
- *Able to identify and apply resources*--Scheduling is currently done using hard copy forms and in-person negotiation, which makes it difficult to develop and maintain an optimal plan.
- *Able to adapt to surprise*--Use of CSE makes understanding what goes right, and what occasionally does not, a routine learning process that can improve the ability to adapt.

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Next Steps

- Develop a prototype compatible with IT requirements
- Test and validate the prototype in concert with other IT solutions that are currently in use
- Field in a clinical setting

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Your comments and correspondence are welcome.

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Appendix S. Developing a Cognitive and Communications Tool for Burn ICU Clinicians. *Military Medicine*. Association of Military Surgeons of the United States (AMSUS). *(in press*)

ABSTRACT

Background: Burn intensive care unit (BICU) work is necessarily complex and depends on clinician actions, resources, and variable patient responses to interventions. Clinicians use large volumes of data that are condensed in time, but separated across resources, to care for patients. Correctly designed health information technology (IT) systems may help clinicians to treat these patients more efficiently, accurately, and reliably. We report on a 3-year project to design and develop an ecologically valid IT system for use in a military BICU.

Methods: We use a mixed methods Cognitive Systems Engineering approach for research and development. Observations, interviews, artifact analysis, survey and thematic analysis methods were used to reveal underlying factors that mold the work environment and affect clinician decisions that may affect patient outcomes. Participatory design and prototyping methods have been used to develop solutions.

Results: We developed 39 requirements for the IT system and used them to create three use cases in order to help developers better understand how the system might support clinician work to develop interface prototypes. We also incorporated data mining functions which offer the potential to aid clinicians by recognizing patterns recognition of clinically significant events, such as incipient sepsis. The gaps between information sources and accurate, reliable, and efficient clinical decision that we have identified will enable us to create scenarios to evaluate prototype systems with BICU clinicians, to develop increasingly improved designs, and to measure outcomes.

Conclusion: The link from data to analyses, requirements, to prototypes and their evaluation ensures that the solution will reflect and support work in the BICU as it actually occurs,

improving staff efficiency and patient care quality.

BACKGROUND

Patients who are admitted to the Burn Intensive Care Unit (BICU) present healthcare teams with unique challenges as a result of their fragile and often unstable condition. Their complex combinations of life-threatening injuries and illnesses make trauma and surgical care for these patients necessarily complex. Clinicians from 15 specialties must work together to make effective decisions, develop treatment plans, assess patient progress, and refine care management over time. This team must also account for limited resources and must adjust their course of treatment according to variable patient responses to interventions.

Care also relies on clinician *cognitive work,* which includes decision making and related activities such as problem detection, sense making, and building common ground among the care team members. Under time pressure, ICU Clinicians must rely on a large volume of data that is separated among multiple sources. The decisions clinicians make are only as good as the information that is available and important (salient) when the decisions are made. Because of this, the Institute of Medicine[1] recommended improving access to accurate, timely information, and making relevant information available at the point of patient care.

Research and development for this project is being conducted by Applied Research Associates, Inc., an 1100-member science and engineering consulting firm, which is creating a decision and communications support system that will serve a 16-bed military tertiary care BICU. This Cooperative Communication System (CCS) is expected to enable the healthcare team to remain connected to information about each patient and to each other across time and location as the team delivers care. The CCS will keep providers informed of a patient's status, and of other healthcare providers' patient care activities, enable the staff to understand goals,

objectives and tasks related to each patient, and to reconcile differing points of view. Its decision and communication support and machine learning features will make it possible for clinicians to make more accurate and timely diagnoses, to perform more timely and appropriate tests, and to make better plans to optimize patient care. Use of the CCS is expected to improve the availability of information and the synchronization of care among BICU team members, which in turn are expected to improve patient outcomes.

This paper describes rigorous field study, analysis, requirements, and information design and programming to design and develop an ecologically valid IT system.

METHODS

The CCS research team is using a mixed methods Cognitive Systems Engineering[2,3](CSE) approach for this study. The CSE approach includes methods that are particularly well- suited to both learn about behavior and cognition as humans confront complexity in work settings such as the BICU and to develop tools to support their cognitive work. The approach translates knowledge about human cognitive performance to develop solutions, including information system interface design.4 In this study, knowledge that clinicians need includes vital signs and lab values that one would expect would matter in trauma and surgical care decision making. Knowledge also includes unexpected data patterns that matter, but are difficult to detect.

As a "systems engineering" methodology, the CSE approach includes all of the agents that can act in the work setting: clinician and support staff, tasks, information sources, the facility, and more. Figure 1 illustrates five phases in the approach and how the activities in each phase relate to phases of this project. As Figure 1 shows, CSE phases include data collection, data analysis, and solution development. Integration of these five phases ensures that the solution the CSE process produces is inherently valid by being grounded in worker and work setting data. Each element in the solution the CSE approach produces can be traced back through

requirements, through analyses, to the original data. The ability to identify each element among workers, work setting, and tools can also help designers to anticipate shifts and unintended consequences that can happen when new IT such as the CCS is introduced.[5] The CSE approach has been proven to successfully study cognitive activity in complex field settings in high hazard sectors such as defense, national security, nuclear power plants, and law enforcement. The project team has recently used CSE to perform work on behalf of the Department of the Army,[6,7]Chief of Naval Operations,[8] Office of Naval Research,[9] and Department of Homeland Security.[10]

Our project team studied clinicians who work in a 16-bed, American Burn Association accredited regional referral burn center that is a part of a 450 bed, academic, military, Level 1 trauma center. The team obtained approval for human subject research from the funder and research site Institutional Review Board and obtained informed consent from all participants.

In Year 1 the research team used data collection methods (observations, interviews, surveys and artifact analysis) to go beyond surface descriptions (phenotypes) that revealed underlying patterns (genotypes) of systemic factors that mold the work environment and affect clinician decisions.

Data Collection

A team of 2-4 researchers made four week-long data collection visits to the research site, and coordinated additional collection with an on-site research nurse between visits. During these visits, they performed the following data collection methods:

- Observation of clinical teams as they provided patient care and managed the unit. Team members conducted 31 observations with the BICU staff, including bedside, charge and wound care nurses, residents, attending physicians, and physical, occupational and respiratory therapists. These sessions involved shadowing a single person and asking

them to talk aloud as they completed their work. Use of probe questions enabled researchers to request background and clarifying information in context to better understand motivations, information use, and decision making.

- Forty-nine semi-structured Cognitive Task Analysis[11] interviews lasting between 30 to 90 minutes each with members of the BICU clinical staff elicited knowledge about their background, perspectives, work activity, information sources, and challenges they face.
- Artifact analysis of computer-based and hard copy information sources that clinicians use in their work, including sign-out sheets, personal notes, status boards, and information system and equipment displays.
- Brief surveys to identify patterns, such as work team relationships (usually conducted by the on-site research nurse in-between research team visits).

Data Analysis

The research team analyzed data collected from four week-long site visits and research nurse support at the site between visits. Through the following eight steps (Figure 2), their analyses identified clinician goals and barriers to goal achievement.

- *Initial data review and extraction of emerging themes to* review and analyze interview and observation notes from each site visit.
- *Systematic data review and coding to reveal* thematic categories developed during working sessions, and code interview sections to relate them to each theme.
- *Review and interpretation of coded data.*
- *Findings synthesis and integration,* and reflection on newly-collected data.
- *Development of initial requirements for the CCS,* following synthesis activity

- *Preliminary validation of findings* to present the challenges/barriers and initial requirements to a select set of BICU clinicians in order to obtain an initial appraisal of the findings by verifying accuracy and identifying possible gaps.
- *Analysis of cognitive work* to provide the basis for analyzing the cognitive work requirements of BICU clinical teams and distil a descriptive model.
- *Artifact analysis* of the forms and documents that the Burn ICU clinical teams use, in order to more fully understand the kinds of information they seek, use, and share with one another.

The team used results from the data analysis to develop requirements that guided CCS prototype development and assessment (see Results, Table 1).

Participatory Design

Research, software development, and machine learning team members met with the clinical co-PI (JP) for a two-day data analysis and design session to refine and revise design requirements. The team also held a similar design session a few weeks later at the research site to capture clinician insights. In these sessions, representatives from all of the clinician groups that work in the BICU proposed system design ideas that might facilitate timely, effective, and efficient patient care. The sessions provided the interface designer with beginning concepts for further development and refinement. The research team also updated and refined the use cases that the software development team would need.

RESULTS

One hundred fifty-one BICU clinicians and staff members representing all unit roles consented to participate in this research and many were subjects of interviews and observation. Roles included attending physician (surgeon, intensivist), fellow, resident, physician assistant,

respiratory therapist, occupational/rehabilitation therapist, wound care specialist, dietician, bedside nurse (RN, LVN), unit nurse (e.g., infection control, CNS), care manager, ward clerk, chaplain, volunteer, other physician (e.g. anesthesiologist, consulting MD's), ancillary services, and student (medical, nursing). Members of this sample and each of the roles also participated in design workshops.

Year 1 results showed that the IT solutions that are currently available to BICU clinicians are not sufficient for clinician information needs. This is because current solutions do not help clinicians to efficiently drive down uncertainty at the individual and the team level. This compels clinicians to exert cognitive effort find and model information that is stored within and across multiple health IT systems in order to make decisions. To counter this, we identified 21 barriers to effective clinical care and recommending 39 requirements for the CCS prototype. These requirements were further developed into rough, then increasingly refined, information displays through creative design workgroups and repeated interviews and surveys. Data analysis identified problems that current health IT solutions present, 21 barriers to cognitive work on the BICU, and developed 39 CCS requirements.

The Problem

The following examples demonstrate difficulties using current healthcare IT, such as finding important (salient) information, that the CCS is intended to address:

> Example 1: "*Patient on insulin drip (which is tracked on the medication flow sheet and the in/out flow sheet) but the patient was not getting hourly blood glucose measurements (which are tracked on the labs and vital signs flow sheets). Small example, but the patient's blood glucose on re-check after six hours was < 30."*

Example 2: *"Ok, I'm trying to identify what possible new medication might have caused a patient's liver to start to fail (this same scenario could apply to any system). There is NO way for me to organize the data in such a way that I can see: Vital signs, Labs, Medication*

at the SAME time. I must do this manually. This is true in [commercial IT system] too. We should be able to do this, especially if we can assign a medication to a system, and potentially unassigned it."

Example 3: *"Ordered a right upper quadrant ultrasound yesterday. Turns out, the patient had several of these in the past, not necessarily in the last month (last was in July), all with similar results - difficult to see the gallbladder. [We] (d)id a different study today. Probably would have saved at least the cost of the procedure yesterday had I know this...."*

Barriers and Requirements

Each of the barriers that the team discovered presents an opportunity to learn how the CCS can support better care coordination. Using the barriers, the team created requirements for the CCS that would enable clinicians to overcome them (Table 1). The first barrier provides an example:

No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.

The requirement states how the CCS solution can help to overcome the barrier:

System shall provide access to a plan of patient care, visible to all care givers responsible for that patient that includes:

Current patient status and top-level assessment;

Goals and priorities for those goals;

Changes/updates, such as indication that plan is being updated when one caregiver is working on it;

Schedule of activities and any changes, timeline;

Orders and their status;

Identity and contact information for patient's care team

The collection of requirements supports development of a number of use cases. They also guide the interface designer's configuration of display content and layout, and software developers planning for interactive features.

Use Case

A use case is a narrative description that suggests how a system might be used. By assembling requirements into a description, software developers can get a sense of how the system will operate in order to support cognitive work on the unit. The first paragraph of a use case for access to a patient care plan that was described above, describes how each of these features (shown in bold type) would serve clinician needs.

At 0630, a bedside nurse has started his preparation for the day ***shift*** *by reviewing information on the patient he is responsible for. Opening CCS, he can see a* ***roster of patients on the unit****, chooses his patient's* ***"at-a-glance" view*** *that shows* ***recent vital signs, current orders, medications, care plan,*** *and* ***notes from the night shift****. He checks the patient's standing* ***care plan*** *and* ***treatment goals*** *(from the electronic healthcare record), and* ***reviews orders*** *(from the laboratory test database) that are pending as well as the day's* ***care***

activities that the Wound Care team, Respiratory Therapists, and Physical Therapists *have recommended and* ***what times*** *they can perform them.*

Both software development and machine learning team members are using these requirements and use cases to develop, evaluate, and refine interface prototypes.

After translating analysis findings into concise problem statements and information system requirements, the team developed a number of visual representations to describe BICU cognitive work and key resources that clinicians use (model of cognitive work, care team, information sources) and prototype information displays.

Model of Cognitive Work

Complexity can hide underlying systematic patterns of cognitive work that clinicians perform in the BICU. Figure 3 illustrates these patterns that our CSE approach revealed.

The top level of the model (at left) shows the unit's primary role in cognitive work: synchronization of patient care both among clinicians and over time. The next level down includes activities that all unit members perform in order to accomplish synchronization: clarification, coordination, negotiation, and anticipation. Supporting tasks make each of those activities possible. Each task can be observed in the way that clinicians interact with each other and use information sources to minimize uncertainty. Requirements that the team developed from these tasks indicate possible leverage points, or opportunities, to improve synchronization.

Patient Care Providers

Knowing what to include and exclude is part of the challenge in the study of a complex system such as the BICU. To do that, the team asked 8 nurses, 5 respiratory therapists, 2 physical therapists /occupational therapists, 1 nutritionist, and 1 physician on the BICU "Who do you communicate with to do your work?" The resulting network is being used to guide development of role-specific screens in the prototype versions of the CCS.

Information Sources

Artifact analysis developed an inventory of the information sources shown in Figure 4 that clinicians rely on to provide patient care. Sources ranged from physical items (e.g., status boards) to communications (e.g., cell phones) to computer databases (e.g., the electronic health record) and paper and electronic sources (e.g., arterial blood gas monitor). Disconnection among most of these sources was one of the barriers the team's inquiry revealed. The need for clinicians to transcribe and re-enter data from one system to another detracts from time to care for patients, and also presents the opportunity for inaccurate transcriptions.

Information Displays

Based on the participatory design sessions, the design team developed several versions of the interface design. This resulted in an information design prototype that was based on Year 1 findings and requirements with views organized according to clinician needs.

- Patient View—Figure 5 illustrates how critical variables are shown for each patient organized by neural, cardiac, respiratory, gastrointestinal, pulmonary, and renal systems. A "parent-child" display tab feature serves as a kind of tab reference to see more detailed material. The view also includes a Wound Flow analysis of the patient's skin and graft condition (developed by the research site), as well as the patient's schedule for the day.
- Multidisciplinary Rounds View—Provides a means for the Charge Nurse to document key details of the daily interdisciplinary rounds that are conducted each morning starting at 0800. Entry of goals, medications, and orders captures patient care decisions, put them in motion, and makes it possible to track their progress through the day.

- Unit Level View—Indicates the location and condition of each patient in the 16-bed unit, and the two operating rooms nearby. Provides a message window to share information that affects the whole unit, and staff members on the unit that shift.

DISCUSSION

Healthcare IT systems must reflect actual clinical practice in order to provide information that will effectively support decision making and related cognitive work of patient care. We have shown how the CSE research approach can be used to identify barriers to decision making, and develop potential solutions to overcome them.

Despite years of effort in medical informatics, a gap remains between the complexities of the clinical work setting and the information systems that are intended to support clinician cognitive work.[12] This is true of the electronic health record (EHR) as well as other healthcare IT such as Computer Physician Order Entry (CPOE).[13] The difference has implications for clinician performance and, ultimately, patient care. The examples in the Problem section of this paper demonstrate how a clinician's inability to find salient information affects clinical decision making. We contend that the reason for this is a failure to accurately reflect the work domain and behavior in the clinical setting.

During this research we have studied individual and team clinician work in actual and controlled settings. Among the findings mentioned above, we have also found issues with healthcare IT displays, including the EHR. The EHR is intended to serve as the central information source for clinicians to use while making patient care decisions. Electronic health records are often linked with other systems, including clinical decision support, and computerized physician order entry. Applications such as dispensing medications can also include interaction with other systems such as bar-coding at medication dispensing, robot for

medication dispensing, and automated dispensing machines. Administrative applications include electronic medication administration records and bar-coding at medication administration.[14] These inter-relationships can have a widespread effect on the work that clinicians perform.

Clinician patient care decisions are based on information that is provided by various means, which increasingly include the EHR. While providing some benefits, the EHR's rapid development has created "…digital piles grown so gigantic, unwieldy and unreadable that sometimes we wind up working with no information at all."[15]Among all of these data, where does the clinician look for what matters when assessing trends and making diagnostic and therapeutic decisions? Do data that matter stand out, or are they obscured by other elements? And how can system developers know what matters? What data matter most to a patient and clinician at the moment they are being considered? Machine learning features we are including in the CCS can be used sort through the "digital" piles to make useful information *salient* (stands out or is prominent).

Figure 5 illustrated an approach to make salient information evident. An order entry page (Figure 6) from the electronic health record at our research site demonstrates some of the issues that can impede the cognitive work of patient care. Five such issues that are shown in Table 2 describe reasons for the gap between clinical practice and the EHR that the CCS project addresses.

Salience—Care decisions rely on finding data that are significant among a large amount of material. The inability to identify key data can divert attention, and delay decisions.

Disregard for Practice—Care for acutely ill patients often depends on the repeated assessment of critical physiologic processes, and clinicians have developed methods to

identify and assess data. These assessments involve inferences from laboratory data that are obtained at intervals. One set of values are consistently depicted in the format that is often referred to as a "fishbone." The fishbone diagram layout evolved through clinical practice as a concise, space efficient representation of clinically relevant values. The seven variables (typically written clockwise from upper left) are concentrations of sodium, chlorine, blood urea nitrogen, glucose, creatinine, carbon dioxide, and potassium. The data are used so frequently that clinicians know the normal ranges. These values are related, and relationships among variables are meaningful. Even so, the EHR does not use this proven approach.

"Keyhole View"—Context is the prerequisite to determine significance. Humans are uniquely suited to understanding the significance of data with respect to the *context* of the current situation. Hard copies can display significant amounts of information in the same plane, making comparison and contrast judgments possible. Limits to what can be displayed using electronic systems narrows the view into data sets. Inability to view data trends or ranges limits the clinicians' ability to place data in context.

Cut-and-Paste Entry—Continued default entry of prior patient data can lead to repetition without sufficient review.

Techno-Centric Measures—Measures of system performance do not translate into patient care improvement. Emphasis on record and database use diverts attention from patient care—the reason why the systems have been created.

Interoperability—Not all units in a healthcare institution adopt systems consistently. For

example, implementation of computerized provider-order entry in one unit does not necessarily result in easy implementation in other units. Mixing paper-based information systems and computer-based systems in various units may increase the potential for misadventures as patients move from one unit to another.

These and other differences from clinical practice indicate why a different approach is needed for healthcare IT (including the EHR) to effectively support clinician, and patient, cognitive work.

Support for Cognitive Work

Automation has traditionally been employed in high hazard settings to replace individuals in the performance of work that is considered to be inappropriate for humans. Rather than replace humans, though, automation needs to *aid* humans as they work to solve problems. The way that a problem is presented can improve or degrade the performance of cognitive work[16] and aiding has typically been directed at the novice level. In fact, aiding is most needed on difficult problems, which are the type of problems that experts confront. As in other high hazard settings, expertise[17] in healthcare is the ability to know what is—and what is not—important.

Healthcare activities rely on the acquisition, portrayal and analysis of therapeutic and diagnostic information as an integral part of individual patient care. The daily work of the clinician requires representations that serve as a map of the ever-changing territory of work that must be successfully navigated.18 What is represented, and how it is represented, depends on the individual and group cognitive work that it is intended to support. Individual elements of information vary enormously in the length of time that they remain reliable, and their weight

depends a great deal on their context. The need for accurate, timely information also exists at the unit level, such as the OR and ICU, where the technical work of unit planning and management directs who will get care, what type of care will be provided, and when it will be provided.

Progress in improving healthcare IT to support patient care relies on going beyond the surface descriptions (phenotypes) of work domains to the underlying patterns (genotypes) of systemic factors.[19] Understanding any work domain and the forces that shape it requires methods that are suited to their study. Human factors[20] and CSE research methods within the naturalistic decision making model[21] have proven value in revealing the key aspects of healthcare work domains such as the BICU in this study to develop valid information displays.

Improvement in IT support for healthcare cognitive work requires repeated, deep looks into the clinical work setting using methods that are suited to the study of individual and team cognitive work in order to find what data truly matter. Use of CSE's decision-making approach to understand patient care settings can inform the development of effective IT support. The salience that results can begin to overcome embedded difficulties with records that, left unattended, will continue to impede clinical care for patients.

As a BICU IT system, CCS is a Force Protection resource to provide optimal support for military patients. Through CCS decision support, clinicians can make more accurate and timely diagnoses, perform more timely and appropriate treatments, and provide evidence-based care that reduces the time lag from "bench-to-bedside" care. As a team tool, CCS builds consensus and efficiency that can be expected to shorten patient length of stay and improve outcomes.

As a networked system, the CCS has the potential to extend beyond the fixed walls of a

hospital to incorporate pre-hospital, contingency operations, and theater evacuations during military operations. Improved communication the CCS affords also facilitates handoff on arrival at the care facility. For example, when a soldier gets injured, a networked communication system could immediately start relaying information to a Forward Surgical Team or Combat Support Hospital to keep the receiving healthcare team apprised of the patient's status so that they can adequately prepare and deliver care.

CONCLUSION

The findings from our CSE study are being used to create an information display that presents salient information, which will spare clinicians from having to find and synthesize it as they do now. This is expected to improve staff efficiency and patient care quality by improving clinician decision making and communication. Specific CCS views sort information according to BICU cognitive work, from preparing for and conducting rounds, to individual patient care, to managing the unit as a whole. The link from data to analyses, requirements, prototypes, and evaluation ensures that the CCS solution will reflect and support work in the BICU as it actually occurs.

The research team's prototype, which can also mine data for relevant information, will be tested and validated using criteria from the first year of research. Use of the CCS is eventually expected to help to decrease missteps, lapses, delays in care, and the morbidities from causes such as wrong medication/dose, infections, and unanticipated emergencies such as cardiac arrest.

ACKNOWLEDGEMENT

The authors express their gratitude to the clinicians who participated in this effort, LTC Kevin Chung, MD, as well as colleagues Greg Rule, Dianne Hancock, LVN, and Nicole Caldwell, RN, for their work on this project. We are also grateful to Dr. Michael O'Connor for contributing insights on salience and the electronic health record.

AUTHORSHIP STATEMENT

Nemeth, C.—Principal investigator, lead author, data collection/analysis, interface design

Pamplin, J.—Co-Principal Investigator, clinical subject matter

expert Anders, S.—Data collection/analysis, requirements

development Strouse, R—Interface design

Grome, A.—Data collection/analysis, requirements development

Crandall, B.—Data analysis, requirements development

Salinas, J.—Task area manager, software development standards

Mann-Salinas, E.—Task area manager, research standards, clinical subject matter expert

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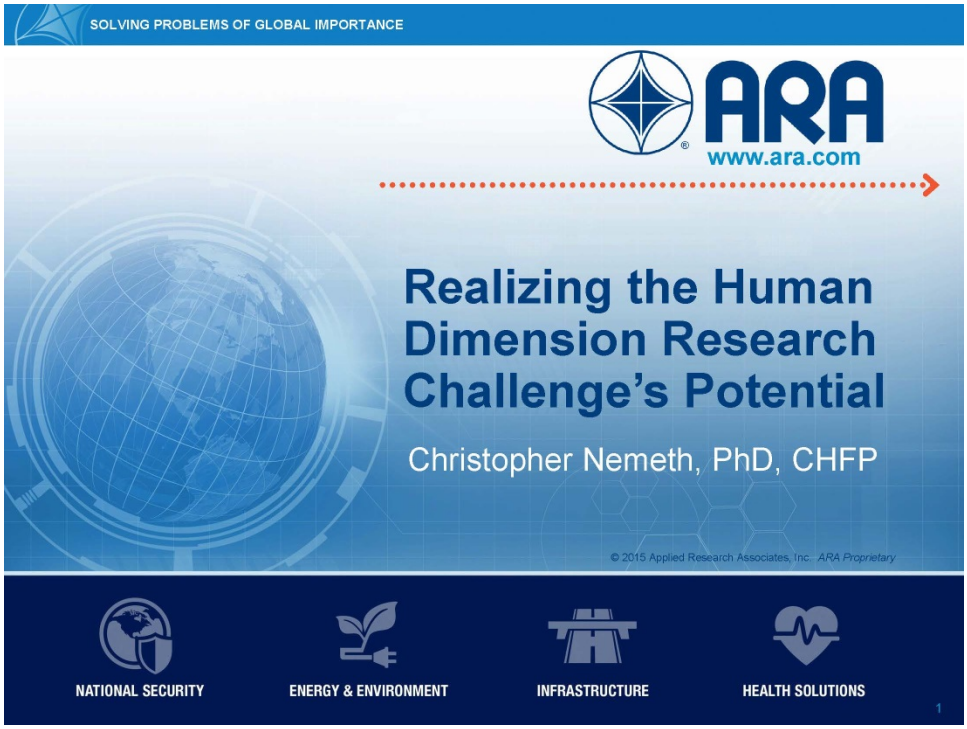
Appendix T. Nemeth, C. Invited presenter: *Realizing the Human Dimension Research Challenge Potential*. Sandia National Laboratories. Albuquerque, New Mexico. 28 July 2015.

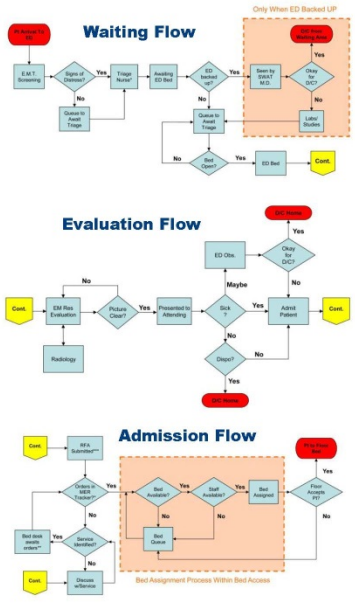


New Venture

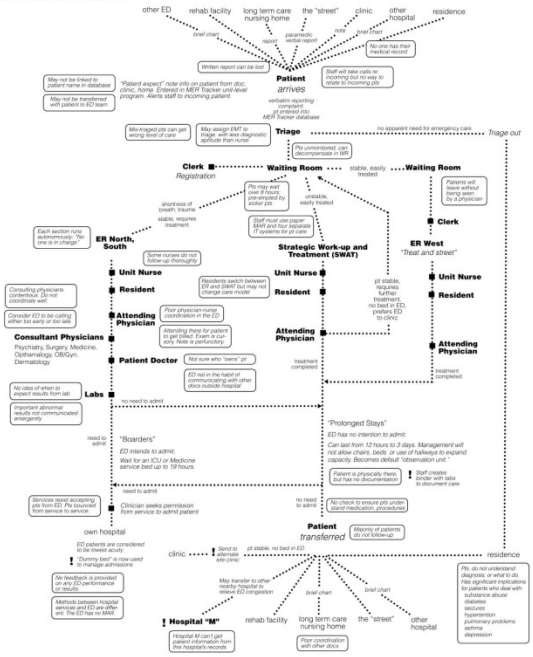
New evolutions in human performance in acquisition:

- USAF Human Readiness Levels
- DoD HFE Standards
- NDIA HSD Congressional outreach

New Venture



New Venture



SOLVING PROBLEMS OF GLOBAL IMPORTANCE

New Tools, New Approaches

Requires being open to new thinking, new tools to engage new challenge

New approaches to development of *socio-technical systems* (Hollnagel and Woods, 2005)

Resilience engineering observes, analyzes, designs and develops systems with the ability to anticipate and adapt to unforeseen demands, and continue operations. (Hollnagel, Woods, Leveson 2006)

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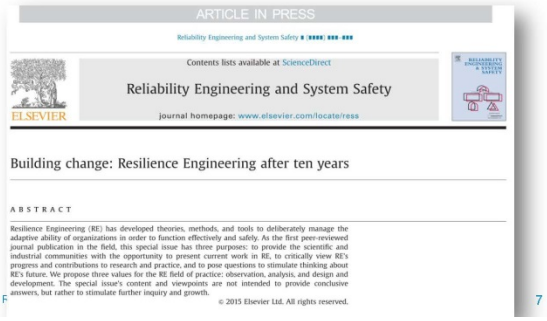
SOLVING PROBLEMS OF GLOBAL IMPORTANCE

New Tools, New Approaches

How can we be better at:

- Observation
- Analysis
- Design and Development



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Reliability Engineering and System Safety ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

journal homepage: www.elsevier.com/locate/ress

Building change: Resilience Engineering after ten years

ABSTRACT

Resilience Engineering (RE) has developed theories, methods, and tools to deliberately manage the adaptive ability of organizations in order to function effectively and safely. As the first peer-reviewed journal publication in the field, this special issue has three purposes: to provide the scientific and industrial communities with the opportunity to present current work in RE, to critically view RE's progress and contributions to research and practice, and to pose questions to stimulate thinking about RE's future. We propose three values for the RE field of practice: observation, analysis, and design and development. The special issue's content and viewpoints are not intended to provide conclusive answers, but rather to stimulate further inquiry and growth.

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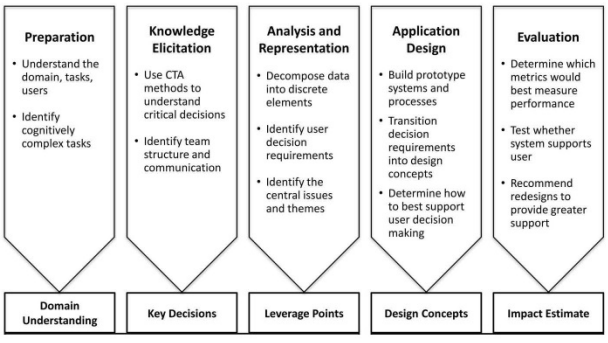
SOLVING PROBLEMS OF GLOBAL IMPORTANCE

New Challenges

- Human factors/ergonomics has experienced issues that the Human Dimension RC may also confront
- Methods used to understand human performance may not be familiar to the Human Dimension RC



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SOLVING PROBLEMS OF GLOBAL IMPORTANCE

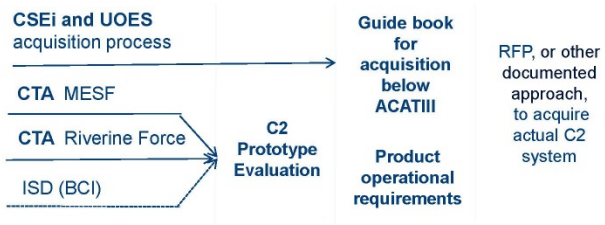
New Opportunities

Example: C2 Upgrade for NECC

SOLVING PROBLEMS OF GLOBAL IMPORTANCE

Scope

- Research design ensured direct connection from data collection through analyses to requirements and C2 display
- Common, Shared, Unique Capability definitions
- C2 prototype for ONR, NECC N9, OPNAV and PMS 480
- Human-Centered Design System Attributes
- Human-centered design process for JCIDS to 5000 ACAT IV/AAP or below



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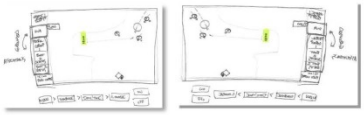
Key Findings

Operators needed C2 system that:

- Supports cognitive work of operators, supervisors, and commanders *(deep understanding of human cognition)*
- Supports shared understanding and anticipation of the operational picture across command hierarchy and at multiple sites *(coordination)*
- Supports potential threat detection, assessment and handling *(human-machine interaction)*
- Enables early diagnosis of system/communications failures *(graceful adaptation)*
- Promotes resilience during complex situations and/or system failures *(increases adaptive capacity)*

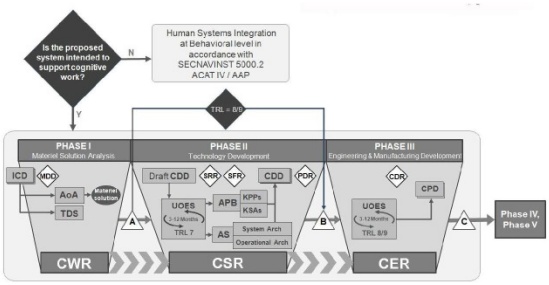
Mission	CTF 56.5 Mission: Provide centralized planning control, coordination and integration of maritime expeditionary assets to protect strategic shipping and military assets operating in coastal areas, anchorages and harbors.
Cognitive Demands	**Understand Operational Picture**; **Establish, Maintain Common Ground**; Share Information; Detect Potential Threats; Manage Communications Equipment; Collaborate w/ coalition forces
Barriers	**Poor Information Sharing**; Disruptions ir Information Flow, Info-Sharing, Distortions…; Failure to Train as You Fight; Boredom/ Low Cognitive Workload; Mismatch of Tools/Equipt. And Operating Environment; Unreliable Comms; Logistics/ Infrastructure issues; Inadequate Tools/Equipment
Information Requirements	**Provide integrated real-time picture across C2 nodes**; Provide up-to-date information about resources available to watch standers in-theater; Provide information to enable C2 watch planning
Design Concepts	

Operational Requirements, OV3, OV6, Scenarios

- Requirements: Information, Operational/Organizational, Training, Architecture, Technology
- OV3/OV6, KPP's, KSAO's
- Display Assessment Criteria

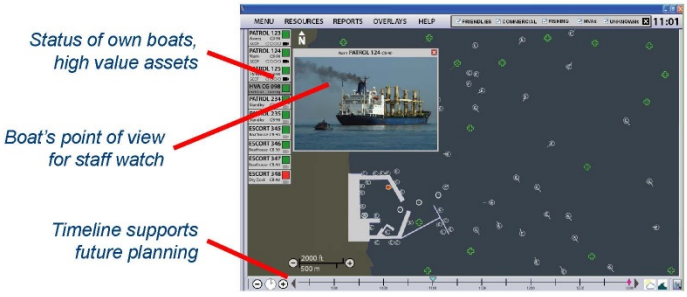
Guidebook

Sixty-page guide for requirements and program managers, NSWC staff, contractors to integrate human-centered design into systems acquisition.



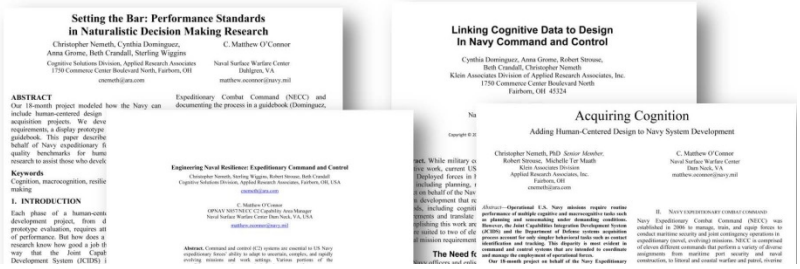
JEC3 C2 Display

- Obtained Raytheon Solipsys partial software
- Developed common operating picture display
- Created Flash illustrations, programmed prototype
- Evaluated rough concepts, operating prototype with MESF and Riverine subject matter experts.



Results

- Common development language for OPNAV, NAVSEA staffs to use
- Tools (requirements, OV's KPP's. KSAO's) to manage ACAT IV, AAP acquisition in JCIDS context
- Incorporation of human-centered design that reflects operator cognitive work
- Validated system solutions
- Professional community awareness through series of peer-reviewed publications



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SOLVING PROBLEMS OF GLOBAL IMPORTANCE

New Opportunities

Example: Cooperative Communication System

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Research Site

- Burn ICU in tertiary care medical center,
- 16 beds, 2 reserved to serve as a post-anesthesia care unit (PACU),
  1 dedicated to support Extracorporeal Membrane Oxygenation (ECMO).
- Other nearby units support the ICU, including a step down unit, burn operating room, and outpatient clinic.
- Population averages around 8 patients but as high as 13
- Patients have severe affliction from chemical, mechanical or electrical burns, or burn-like afflic necrolysis (TENS).
- Length of stay ranges from days to months.

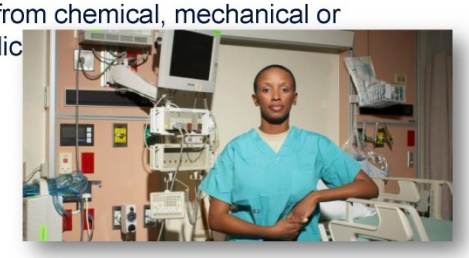


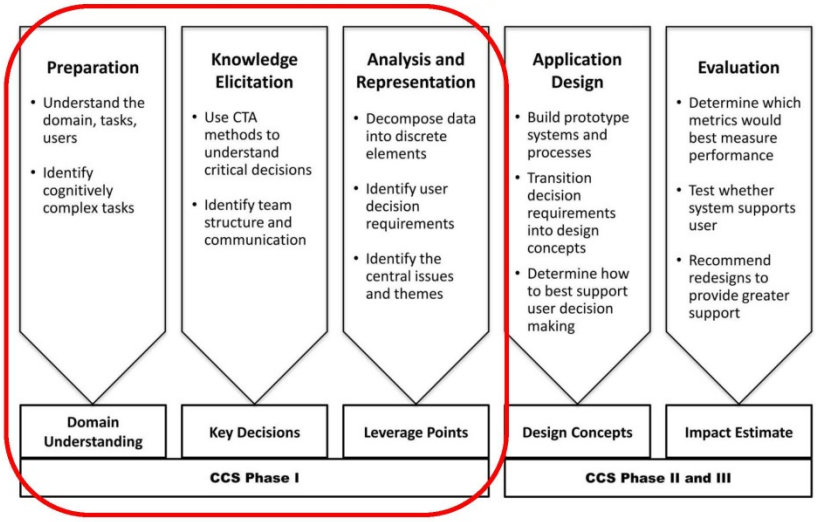
Photo: Dept. of the Army

Research Design

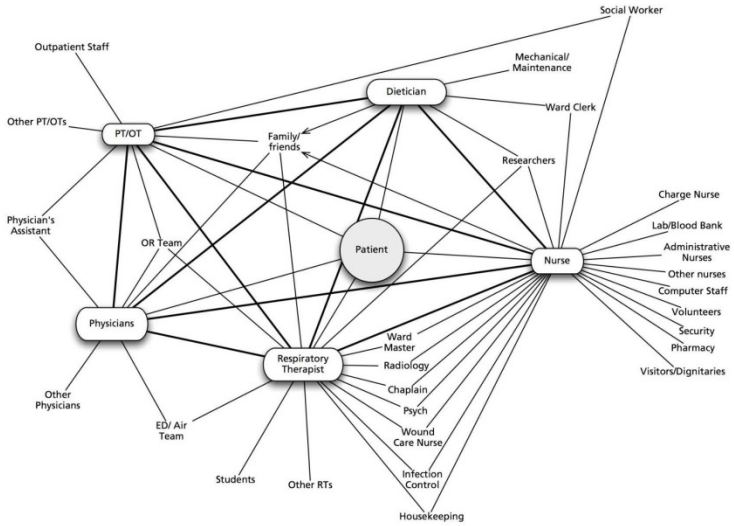
- Goal is to improve care by better supporting the judgment of individuals and teams who care for patients through a cognitive aid that also assists communication.
- Three phases that are scheduled to take roughly a year apiece: foundation research, cognitive aid prototype development, and prototype assessment.

Photo: Dept. of the Army

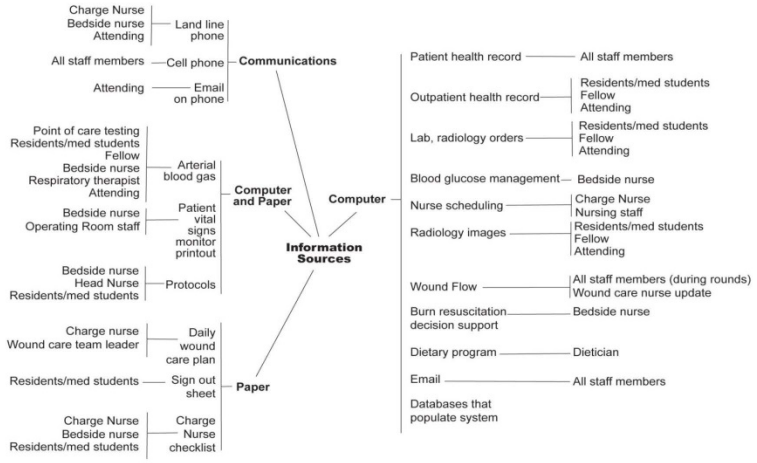
Cognitive Systems Engineering Phase 1



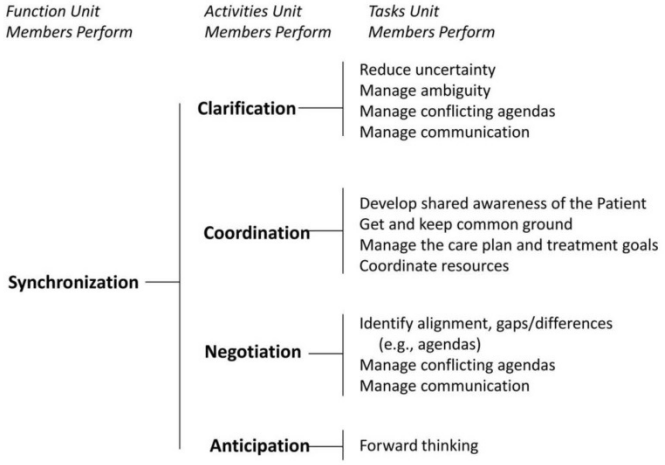
BICU Patient Team



BICU Information Sources



BICU Cognitive Model



Barrier

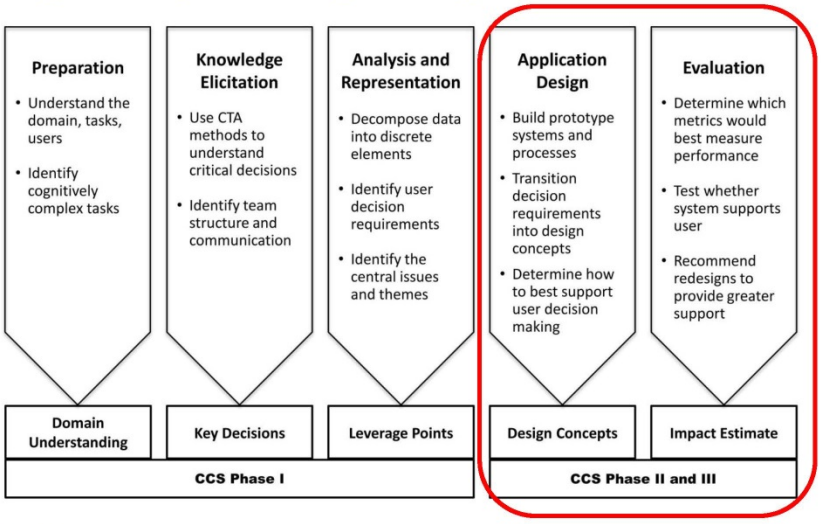
No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.

Requirement

System shall provide access to a plan of patient care, visible to all care givers responsible for that patient that includes:

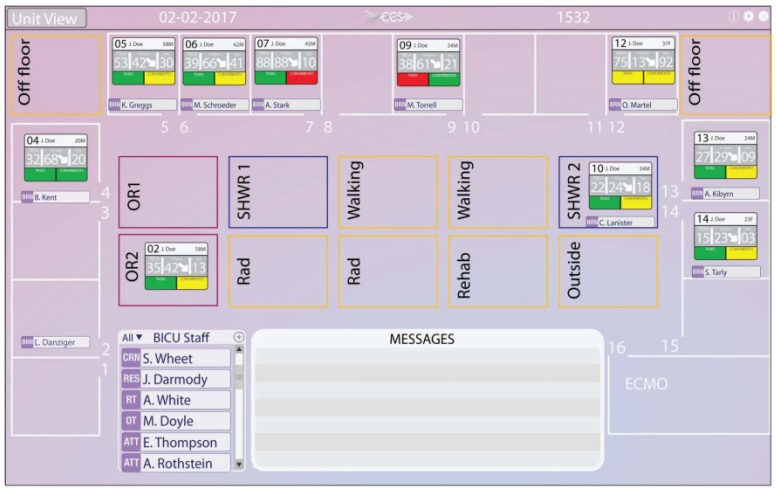
- *Current patient status and top-level assessment*
- *Goals and priorities for those goals*
- *Changes/updates, such as indication that plan is being updated when one caregiver is working on it*
- *Schedule of activities and any changes, timeline*
- *Orders and their status*
- *Identity and contact information for patient's care team*

Cognitive Systems Engineering Phases Two, Three



Patient View

Unit View



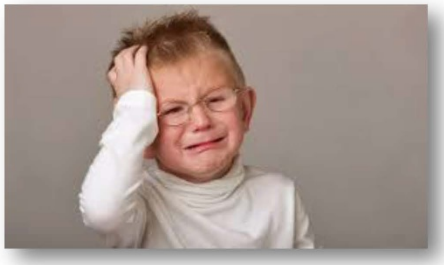
Resilience

Three characteristics that CSE can assist:

- *Being self-aware*--Disconnection among specialties is aggravated by disconnected information sources.
- *Able to identify and apply resources*--Scheduling is currently done using hard copy forms and in-person negotiation, which makes it difficult to develop and maintain an optimal plan.
- *Able to adapt to surprise*--Use of CSE makes understanding what goes right, and what occasionally does not, a routine learning process that can improve the ability to adapt.

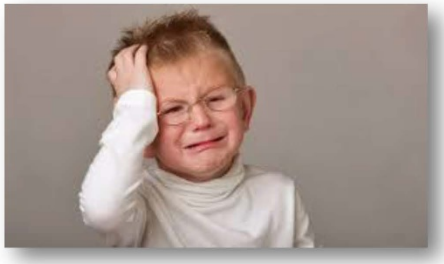
Pop Quiz!

Q. What's the hardest part of this project so far?



Pop Quiz!

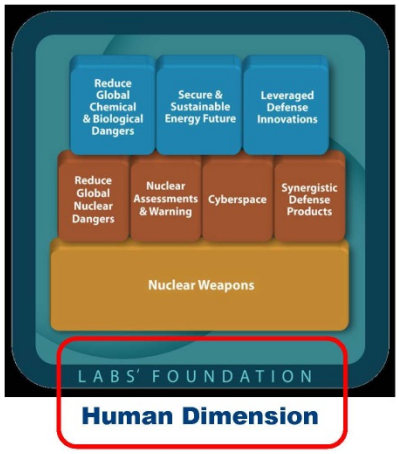
Q. What's the hardest part of this project so far?
A. Access to patient data.



from 1985, in a previous cycle

intelligence does not lie in devices, artifacts, computations, algorithms, or automata

intelligence is in the creation and utilization of capabilities in the pursuit of human purposes



New Results

The Human Dimensions Research Challenge might yield:

- Authentic insight into human cognitive performance
- Gracefully adaptive system architectures
- Methods and skills that enable technical professionals to develop them
- Applications that leverage increased adaptive capacity, such as the analysis of big data, which can mitigate cognitive overload

Your comments and questions are welcome:

Christopher Nemeth, PhD

Cognitive Solutions Division
cnemeth@ara.com
937-825-0707

Appendix U. Poster Presented by Dr. Christopher Nemeth at the Military Health System Research Symposium (MHSRS), Fort Lauderdale, Florida. August 2015.

Building Cognition through Burn Intensive Care Unit Decision and Communications Support

Christopher Nemeth, PhD[1], Jeremy Pamplin, MD[2], Anna Grome, MS[1], Dawn Laufersweiler[1], Josh Blomberg[1], Tony Hamilton[1], Jose Salinas, PhD[2]

1. Applied Research Associates, Inc.; 2. United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX

Introduction

Our research team is in the third year of a 3-year project to design and develop the Cooperative Communication System (CCS), an ecologically valid decision and communications IT system for a military burn intensive care unit (ICU). Our purpose is to improve individual and team decision making to improve patient safety and optimize patient outcomes.

Aim/Objective

To improve care by supporting clinical decision-making through the design and development of valid computer-based decision support and communication tools.

Methods

We are using a mixed methods Cognitive Systems Engineering (CSE) approach. Year One CSE methods included observations, interviews, surveys and artifact analysis to develop a distributed cognition model of BICU clinical practice. In Year Two, we developed initial information design and initial software prototypes of the IT system, based on Year One findings. The user interface and data mining functions and are now being programmed to develop increasingly refined prototypes that we evaluate with BICU clinicians at each stage through a mixture of agile and spiral software development methods.

Evaluation, including usability assessments scheduled for October 2015 and January 2016, will verify improvements to decision making that result from clinician use of the CCS.

Results

Year Two results have translated Year One data and requirements into system features that will enable clinicians to overcome barriers, from uncertainty about patient and team status to decisions about diagnoses and treatment. A Unit View supports resource allocation and prioritization, care planning and coordination. An individual Patient View enables the clinician to increase information salience by choosing what is displayed and how it is shown. This allows for the creation of relational information displays such as a "cardiovascular," "cardiopulmonary," or "cardio-renal" that may help clinicians answer questions about patient condition or treatment effects. Scheduling support improves unit efficiency by making opportunities for care evident, and saving "missed" opportunities for care such as a chaplain visit, or rehabilitation.

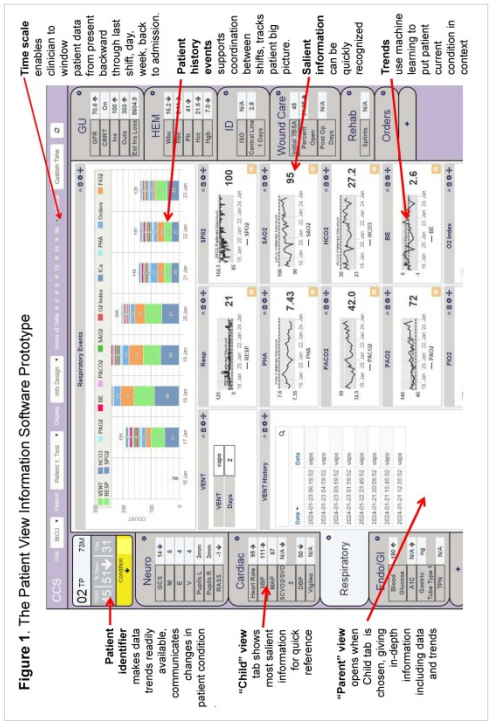


Figure 1. The Patient View Information Software Prototype

Figure 2 CCS Core Functions

Patient View Enables clinicians to view patient systems in one unified view that can be configured to individual preference. Improves resource use and prioritization, and care coordination and planning.

Scheduling Provides means for unit managers to identify available team resources, assign to patient care teams.

Patient Identifier Presents critical information for quick recognition of patient condition, trends.

Unit View Enables unit managers to appreciate condition, trends among and across all patients on the unit.

Order Management Tracks orders entered, pending, and delivered to reduce uncertainty about therapeutic interventions.

Smart Checklists Provides Charge RN with required steps to ensure compliance with guidelines, and better coordinate unit task performance at interdisciplinary rounds.

Tasking, Messaging, Alerting Provides care team members with means to pose and answer critical questions related to patient cared, improving situational awareness and response times.

A Patient Identifier enables the staff to scan among and across patients and recognize care needs at a glance. Order Management minimizes uncertainty on diagnostic and therapeutic plans, status, and results. Smart Checklists track quality measures in real-time to ensure essential evidence-based care is accomplished. Tasking, Messaging, and Alerting support the development and maintenance of common ground among clinicians through real time communication.

Each view provides benefits to the clinical team. Task oriented/role based views ensure only salient information is displayed. Clinician configuring of patient displays improves understanding of patient trajectory. Machine learning makes it possible to identify patterns such as trends, comparable patients and care regimens, and metadata on how clinicians use the system

Discussion

Clinician information needs change according to patient condition, patient problem, clinical task, and clinician role and experience. Through CSE, we have identified seven core functions for our CCS health IT system to support clinical decision making information needs. The CSE approach produces decision support tools that are ecologically valid and inherently useful by matching information to task. More efficient, reliable collaboration among members of the ICU staff who use the CCS is expected to improve patient safety and patient outcomes.

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Acknowledgement

We offer thanks to Greg Rule, PE and Nicole Caldwell, RN for their help with this project, which is supported by a grant from the US Army Medical Research and Materiel Command Congressionally Directed Medical Research Program (CDMRP) (W81XWH-13-2-0011).

MHSRS-15-0173, Board 3007

Appendix V. ***Valid Point of Care IT for Improved Decision Making Precision Nemeth, C., Pamplin, J.C., Grome, A., Laufersweiler, D, Blomberg, J., Hamilton, A., Salinas, J. (In review).*** **National Institutes of Health (NIH) IEEE Engineering in Medicine and Biological Science (EMBS) Strategic Conference. November 2015.**

Valid Point of Care IT for Improved Decision Making Precision

Christopher Nemeth, PhD, Senior Member, IEEE, Josh Blomberg, Christopher Argenta, LTC Jeremy C. Pamplin, MD, Jose Salinas, PhD, Maria Serio-Melvin

Abstract—**Precision in clinician point of care decisions relies on awareness of and access to the most important, or *salient*, information. Barriers to clinician cognitive work such as poorly-crafted information technology, delay patient care and increase care cost, length of stay, and the potential for misadventures. We report on the Cooperative Communication System (CCS) project to develop a real time IT system to support Burn ICU individual and team cognitive work and communication using Cognitive Systems Engineering methods. More efficient, reliable collaboration among members of the ICU staff who use the CCS is expected to improve patient safety and optimize patient outcomes.**

I. Cooperative Communication System

Our research team is in the third year of a 3-year project to develop the Cooperative Communication System (CCS) for a 16-bed military burn intensive care unit (BICU). The CCS is an information technology (IT) system that is intended to improve individual and team decision making and communication in the BICU.

II. Methods

We have used a Cognitive Systems Engineering (CSE) [1] mixed methods research approach to study cognitive work in the BICU. Five phases from preparation, to knowledge elicitation, analysis and representation, application design, and evaluation, ensure the solution that the process produces is grounded in data that are drawn from study of the clinicians and BICU work setting. Methods included structured interviews, surveys, artifact analysis, table and diagram development and thematic analysis [2]. The process revealed 20 key challenges and barriers to cognitive work on the BICU, and translated them into concise problem statements and 39 information system requirements. A descriptive model of Burn ICU cognitive work showed how tasks and activities synchronize care. Use cases described to developers how the system is intended to work [3]. Each formed the basis for an interactive prototype (Figure 1) that is now being evaluated on the BICU. Machine learning algorithms will reveal patterns, such as trends and previous patients who had similar traits and treatments, which would otherwise be undetectable.

This work is supported by the US Army Medical Research and Materiel Command under Contract No.W81XWH-12-C-0126. The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation. In the conduct of research where humans are the subjects, the investigator(s) adhered to the policies regarding the protection of human subjects as prescribed by Code of Federal Regulations (CFR) Title 45, Volume 1, Part 46; Title 32, Chapter 1, Part 219; and Title 21, Chapter 1, Part 50 (Protection of Human Subjects).

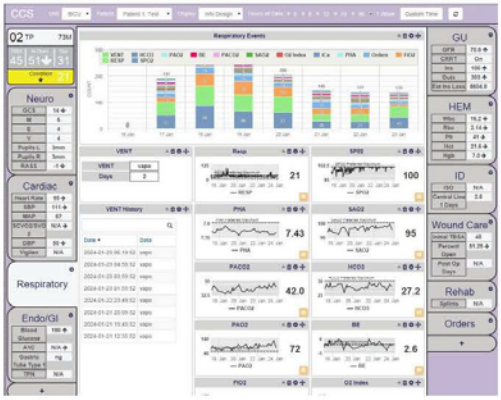

Fig 1. Patient View. *Copyright © 2015 Applied Research Associates, Inc.*

III. Summary

Precision in patient point of care relies on going beyond the surface descriptions (phenotypes) of work domains to reveal and understand the underlying patterns (genotypes) of factors that mold the domain [4]. Support for healthcare cognitive work requires repeated, deep looks into the clinical work setting using methods that are proven in the study of individual and team cognitive work, to find and present salient data. Use of the CSE approach to understand patient care settings can inform the development of effective IT. The salient information displays that result can begin to overcome embedded difficulties with current IT, including health records.

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Appendix W. Support for ICU resilience: Using Cognitive Systems Engineering to build adaptive capacity. *Proceedings of the Systems Man and Cybernetics Society 2014 International Symposium*. Institute of Electrical and Electronic Engineers. San Diego, California. October 2014.

Support for ICU Resilience

Using Cognitive Systems Engineering to Build Adaptive Capacity

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Abstract—**Sensitivity to patient needs makes clinicians the primary source of adaptive capacity, or *resilience*, in the intensive care unit (ICU). Work setting complexities and contingencies make cognitive work in this setting particularly challenging. A IT-based system to support individual and team decisions and communication would increase clinicians' capacity to adapt. We report on a 3-year project now underway to develop such a system. During the first year, our research team used Cognitive Systems Engineering (CSE) methods to reveal characteristics of the work setting, goals, barriers, and individual and team initiatives to overcome barriers. Our data analyses identified requirements for the IT system that were embodied in use cases, as well as in first draft prototypes of the system architecture and user interface. Our team is currently evaluating the interface prototype for face validity and refining details prior to starting programming. Interactive prototypes will be evaluated against criteria identified in field research to ensure validity. The resulting system is expected to improve staff decision making ability and communications with an expected improvement in unit adaptability. Shared decisions based on better information about procedures and resources are expected to improve staff efficiency and decrease missteps, lapses, delays in care, and the occurrence of morbidities including wrong medication/dose, infections, and unanticipated emergencies such as cardiac arrest.**

Keywords—cognition, decision support, communication, healthcare

INTRODUCTION

The U.S. Department of Defense maintains one of the largest healthcare networks in the world. It provides in-patient and out-patient care for the active military, their families, reserve forces, veterans, and local civilians through various military healthcare centers. Caring for patients who are admitted to Intensive Care Units (ICUs) presents healthcare teams with unique challenges that stem from patients' fragile condition and the complex combination of life-threatening injuries and illnesses they face.

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Care for ICU patients necessarily depends on collaboration by staff members from a number of healthcare disciplines and relies on clinician decision making and related activities, which is termed *cognitive work*. Care providers among multiple professions must work together to make effective decisions, develop treatment plans, assess patient progress, and refine care management over time. However, their decisions are only as good as the information that is available and evident when the decisions are made. For this reason, the Institute of Medicine [1] has recommended improving access to accurate, timely information, and making relevant information available at the point of patient care.

Computer systems and knowledge resources are available to support cognitive work, but gaps among these resources and among care providers cause difficulties in healthcare delivery. As a result, critical information that is needed to make decisions is difficult to obtain, is often unavailable when it is needed most, and is difficult to share.

THE COOPERATIVE COMMUNICATION SYSTEM

Healthcare providers and related sources of information including information systems, equipment displays and more comprise a joint cognitive system [2] that is used to manage care activities. Our research team is developing a Cooperative Communication System (CCS) that will serve as part of the joint cognitive system in a 16-bed military tertiary care Burn ICU (BICU). The CCS is expected to enable the healthcare team to remain connected to an individual patient, patient information, and to each other across time and location as the team delivers care. It will keep providers informed of a patient's status, and of other healthcare providers' patient care activities, enable the staff to understand goals, objectives and tasks related to each patient, and to reconcile differing points of view. The decision support that the CCS provides will make it possible for clinicians to make more accurate and timely diagnoses, order more timely and appropriate tests, and make better plans so that patients receive better care. Use of the CCS is expected to improve patient outcomes by improving the availability of information, and the synchronization of care among BICU team members.

The CCS project is organized in three phases. Phase 1 collected and analyzed data to understand the cognitive work and barriers to effective patient care. Results were used to develop CCS system design requirements. Phases 2 and 3 will develop a prototype CCS system and a test bed based on the BICU clinical environment that will be used to evaluate the CCS system with clinicians.

METHODS

Descriptions of clinical cognitive activities rely on understanding how individuals and groups perform them in an actual ("field") work setting. Field research requires immersion to enable the researcher to observe actual work practice and gain insight from deep, repeated inquiries [3].

A. Human Subject Research Approval

Before any data were collected, the research team obtained approval for human subject research from the funder and research site Institutional Review Board. A total of 151 staff members consented to participate.

B. Cognitive Systems Engineering

Understanding any work domain and the forces that shape it requires methods that are suited to its study. The project team is using a Cognitive Systems Engineering (CSE) [4, 5] mixed methods research approach, which is particularly well-suited to study cognitive activity in field settings such as the Burn ICU. Cognitive Systems Engineering is the process of learning about behavior and cognition as humans confront complexity in their work settings, and providing tools to support their behavior. The CSE approach is used to translate knowledge about human cognitive performance such as what is needed to attract attention to unexpected data into principles and techniques to develop solutions including human-computer interface design. [6]

Fig. 1 illustrates five phases in the approach and how the activities in each map to phases of this project.

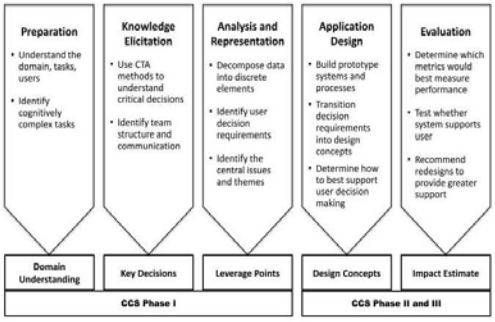

Fig 1. Five phases of Cognitive Systems Engineering. Adapted from [7]

As "systems engineering," the CSE approach includes all agents that can act in the work setting, such as a Burn ICU that is being studied. As Fig. 1 shows, CSE phases span data collection, data analysis, and solution development. Integration of these five phases ensures that the solution the process produces is grounded in worker and work setting data. The ability to identify each element among workers, work setting, and tools can also help designers to anticipate shifts and unintended consequences that occur when new information technology (IT) such as the CCS is introduced [8].

During the first year, the project team collected data over 10 months in four week-long visits to the Burn ICU. During each visit, the team conducted formal interviews, observed and shadowed clinicians, and documented artifacts such as paper forms, information systems, and displays that the staff uses to help them accomplish their work. The team's research nurse helped to collect data when the team was not at the research site. Following each site visit, team members met to analyze the data over multi-day analysis sessions. Data analysis involved several iterative steps. The team reviewed and discussed data multiple times to understand it thoroughly, identify gaps, reduce data, and synthesize it into findings.

The team started with structured and systematic passes through the data to detect patterns, or themes, which described both the ICU work setting and clinician cognitive work. The team used the themes they had developed during the team working sessions to code interview transcripts and observation notes that identified relevant portions for each theme. After data coding, each research team member was assigned a subset of the coded data excerpts to review and interpret. The team held another two-day working session to synthesize and integrate findings. Following the synthesis, the team created initial requirements for CCS according to barriers clinicians face and what the CCS system could do to help clinicians to overcome them. The team then presented the challenges/barriers and initial requirements to two physicians and three nurses on the unit to get their initial appraisal of the findings' face validity.

The analysis provided the means to identify Burn ICU clinical team cognitive work requirements. The team also closely reviewed the forms and documents that the Burn ICU clinical teams use to understand the kinds of information they seek, use, and share with one another. They developed models of the BICU work domain and clinician decision-making and patient care through this process that described the unit's information content and flow that the prototype CCS system will help to manage.

FINDINGS

The project team identified 20 key challenges and barriers to cognitive work on the BICU, then translated them into concise problem statements and information system requirements. They developed representations to describe the BICU environment and key resources that clinicians use there, formulated a set of use cases to describe to developers how the system is intended to work, and developed an initial descriptive model of Burn ICU cognitive work (Fig. 2).

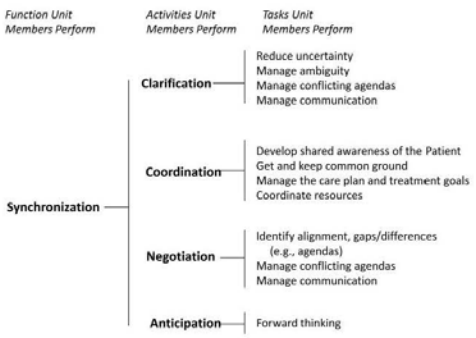

Fig 2. Model of cognitive work

A. Model of Cognitive Work

Complexity can hide underlying systematic patterns in cognitive work. Fig. 2 illustrates these patterns in the BICU. Synchronization of patient care among clinicians and over time is the top level of the model. The next level down includes activities that all unit members perform: clarification, coordination, negotiation, and anticipation, followed by supporting tasks. Each task can be observed in the way that clinicians interact with each other and use information sources to minimize uncertainty. Requirements that the team developed from these tasks indicate opportunities, or leverage points, to improve synchronization.

B. Patient Care Providers

Part of the challenge in this project is to know how to bound it. To do that, the team asked "Who do you communicate with to do your work?" of 8 nurses, 5 respiratory therapists, 2 physical therapists /occupational therapists, 1 nutritionist, and 1 physician. Fig. 3 shows the resulting network that can be used

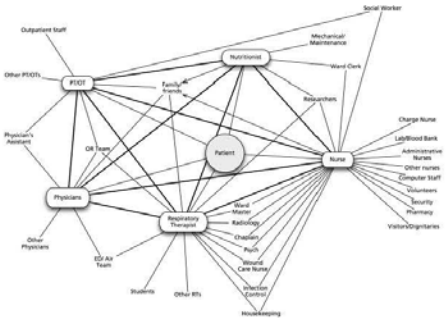

Fig 3. Care provider relationships closest to patient

to develop the CCS interface structure. Thicker lines show that communication was mentioned by both parties, and enable the team to organize interface screens according to clinical roles. This initial network will expand as project work continues, providing the basis for interface views that are organized according to BICU work roles.

C. Information Sources

The team identified a range of information sources (shown in Fig. 4) that need to be used together to manage care and manage the ICU. Ten are computer-based, 3 are paper artifacts, and 3 are computer-based displays that produce a paper printout. Communications including cell and land line phones and email are further information sources. The set describes an inventory of information that matters to the clinicians, and each needs to be included in the CCS solution.

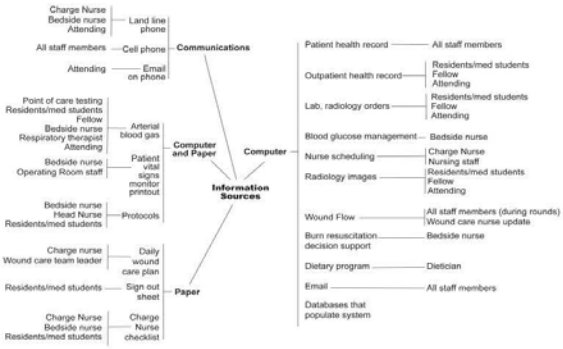

Fig 4. Information sources clinicians use on the BICU

D. Barriers

Each of the barriers the team discovered presents an opportunity to ask how the CCS system can help to improve unit synchronization. Here are four of the 20 barriers that the team discovered:

No effective means exists to synchronize aspects of patient care.

There is a lack of awareness of activities and events that are tightly coupled.

There is no efficient way to communicate changes in patient status across clinical specialties.

Updated information such as results of laboratory cultures is available but is not accessible or visible.

E. Requirements

Using the challenges and barriers, the team created a set of problem statements and then developed concise statements of system requirements for each. The first barrier provides an example:

No effective means to synchronize and adapt different aspects of patient care over the course of a shift, across caregiver team.

The requirement states how the CCS solution can help to overcome the barrier:

System shall provide access to a plan of patient care, visible to all care givers responsible for that patient that includes:

Current patient status and top-level assessment;

Goals and priorities for those goals;

Changes/updates, such as indication that plan is being updated when one caregiver is working on it;

Schedule of activities and any changes, timeline;

Orders and their status;

Identity and contact information for patient's care team

The requirement starts to describe the CCS interface's content and operation. The complete set of requirements, which is directly related through the analyses to the original data, can be used to create a series of use case scenarios.

F. Use Case

The first paragraph of a use case for the above requirement describes how each of these features (shown in bold type) would serve clinician needs.

At 0630, a bedside nurse has started his preparation for the day ***shift*** *by reviewing information on the patient he is responsible for. Opening CCS, he can see a* ***roster of patients on the unit,*** *chooses his patient's* ***"at-a-glance" view*** *that shows* ***recent vital signs, current orders, medications, care plan,*** *and* ***notes from the night shift.*** *He checks the patient's standing* ***care plan*** *and* ***treatment goals*** *(from the electronic healthcare record), and* ***reviews orders*** *(from the laboratory test database) that are pending as well as the day's* ***care activities that the Wound Care team, Respiratory Therapists, and Physical Therapists*** *have recommended and* ***what times*** *they can perform them.*

The information designer and programmers will use these requirements and use cases to develop, evaluate, and refine prototypes in Phases 2 and 3.

DISCUSSION

Methods from CSE can be used to learn the nature of work as it is actually done, and when it is done, by those who do it. This makes it possible to create effective solutions that workers recognize and readily accept. Using knowledge about a work setting such as the Burn ICU can improve workers' ability to operate in spite of significant challenges such as unexpected changes in the type, rate, and volume of care demand [9]. Insights from such studies can also help to contribute to the system's ability to adapt—to be more *resilient* [10]—when workers are confronted with unforeseen challenges.

Three characteristics that CSE can assist include: being self-aware, the ability to identify and apply resources, and the ability to adapt to surprise.

A. Self-Aware

The "cottage industry structure of the national healthcare delivery system" results in "disconnected silos of function and specialization" [11]. This disconnection among specialties is aggravated by disconnected information sources. In this BICU, for example, the electronic healthcare record is not connected to the outpatient record or the database that tracks laboratory test results. Coping with these gaps forces clinicians to invent their own "workarounds." One workaround is to read a display on one system, write needed information onto a scrap of paper, walk to another system display, then key in the information. The process not only opens the door to transcription error, but also takes away from time that could and should be spent caring for the patient.

The CCS can contribute to ICU self-awareness by bridging the many databases that are currently unconnected. The synthesis of information sources would also open the way for data mining to seek and extract meaningful patterns of information that are related to the patient, the unit, or the clinician(s).

B. Able to Identify and Apply Resources

Clinical skills, supplies, equipment, and portions of facilities are routinely assembled to perform each Burn ICU procedure. Patient condition and readiness for a procedure can change, and clinicians, equipment, or rooms can become available or unavailable. Scheduling is currently done using hard copy forms and in-person negotiation, which makes it difficult to develop and maintain an optimal plan.

The CCS can improve the ability to identify and apply resources through scheduling that supports both planning and re-planning (making changes to plans as the day progresses).

C. Able to Adapt to Surprise

We have shown in prior publications [12, 13] how healthcare organizations respond to events, particularly misadventures. With insufficient information on what actually occurs, the response attempts to isolate the cause and declare that it will not happen again. A system that can adapt to surprises and challenges can also be used to learn about its response. The use of CSE makes understanding what goes right, and what occasionally does not, a routine learning process that can improve the ability to adapt.

Data mining being developed for the CCS will make it possible to detect and illustrate trends. Understanding how a patient or group of patients fares over time can improve clinicians' ability to adapt to surprises such as unexpected changes in patient condition.

SUMMARY

Health IT has significant, pervasive effects on health care delivery, patient safety, and care quality. Methods within the of CSE approach can be used to identify patient care and work setting complexities that affect clinicians and the decisions they make. That understanding can be used to develop requirements for computer-based cognitive aids to improve individual and team decision-making and communication.

The system that the CCS project produces is expected to improve clinical decision making and communication as well as unit adaptability. Shared decisions based on better information about procedures and resources are expected to improve staff efficiency. The CCS system is eventually expected to help to decrease missteps, lapses, delays in care, and the occurrence of morbidities including wrong medication/dose, infections, and unanticipated emergencies such as cardiac arrest. As the study continues, the research team will design and develop a prototype that can also mine data for relevant information, then test and validate the prototype using criteria from the first year of research.

ACKNOWLEDGMENT

The authors express their gratitude to the clinicians who participated in this effort, LTC Kevin Chung, as well as colleagues Rob Strouse, Greg Rule, Dianne Hancock, LVN, and Nicole Caldwell, RN, for their work on this project.

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Appendix X. Support for Salience: IT to assist burn ICU clinician decision making and communication. ***Proceedings of the Systems Man and Cybernetics Society 2015 International Symposium.*** **Institute of Electrical and Electronic Engineers. Hong Kong, People's Republic of China.** ***(accepted)*****.**

Support for Salience

IT to Assist Burn ICU Clinician Decision Making and Communication

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***Abstract*—Clinicians need to find and use the most important, or *salient*, information to make optimal patient care decisions. The fragile health of patients who are admitted to a Burn Intensive Care Unit (BICU) requires clinicians and clinical teams to make time-pressured diagnostic and therapeutic decisions based on complex sets of information. Barriers to these decisions, and related behaviors, which we term "cognitive work," delay patient care and increase care cost, length of stay, and the potential for misadventures. We report on the progress of a project to develop a real time IT system to support BICU individual and team cognitive work and communication. Our approach enables clinicians to obtain salient information through three means: role-based data views, ability to personally configure displays, and data mining to reveal trends and patterns. User interface and data mining functions and are now being programmed to develop increasingly refined prototypes that we evaluate with BICU clinicians at each stage through agile software development. Evaluation will verify improvements to decision making that result from clinician use of the CCS. More efficient, reliable collaboration among members of the ICU staff who use this Cooperative Communication System (CCS) will improve patient safety and optimize patient outcomes.**

Keywords—cognition, macrocognition, healthcare, decision support, communication

I. Introduction

The fragile condition and the complex combination of life-threatening injuries and illnesses that Intensive Care Unit (ICUs) patients face present healthcare teams with unique challenges. One of the most critical challenges that ICU care providers face is the need to perform decision making as well as what Cacciabue and Hollnagel [1] termed "macrocognitive" activities, which are "the cognitive functions that are performed in natural (rather than artificial laboratory) decision-making settings." Klein et al. [2] described macrocognition as "the mental activities that must be successfully accomplished to perform a task or achieve a goal." In addition, cognitive work also entails collaboration among staff members from a number of healthcare disciplines who must work together to perform multiple crucial tasks. These include the need to develop treatment plans, assess patient progress, and refine care management over time. Performing these and other care tasks relies on accurate, current information to be both available and evident when decisions need to be made. For that reason, the Institute of Medicine [3] recommended improving access to accurate, timely information, and to make relevant information available at the point of patient care.

Electronic health records (EHR) have been developed to serve as a kind of patient data repository that was intended to enable clinicians to document and retrieve needed patient information. Figure 1 shows the EHR table format that typically requires the clinician to search without providing a way to identify the most important, or *salient,* patient data. As a result, information that is needed to make critical decisions is hard to find, is often unavailable when it is needed most, and is difficult to share. We report on a project to develop a system that makes salient

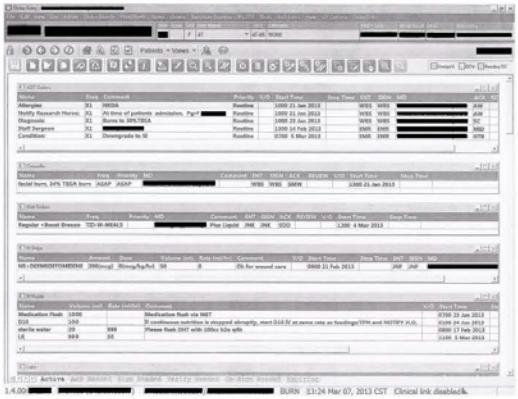

Fig. 1 Example EHR order entry screen (identifying information obscured).
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patient information evident and supports communication among team members in order to optimize ICU patient care.

II. THE COOPERATIVE COMMUNICATION SYSTEM

Our research team is in the third year of a 3-year project to develop the Cooperative Communication System (CCS) for a 16-bed military burn intensive care unit (BICU). The CCS is an information technology (IT) system that is intended to improve individual and team decision making and communication in the BICU, which is expected to optimize patient outcomes and improve patient safety

III. METHODS

A. Human Subject Research Approval

The research team obtained approval for human subject research from the funder and research site Institutional Review Boards. A total of 151 staff members consented to participate.

B. Cognitive Systems Engineering

Understanding any work domain and the forces that shape it requires methods that are suited to its study. The project team is using a Cognitive Systems Engineering (CSE) [4, 5] mixed methods research approach to study cognitive activity in the Burn ICU. The CSE approach (Figure 2) is used to translate

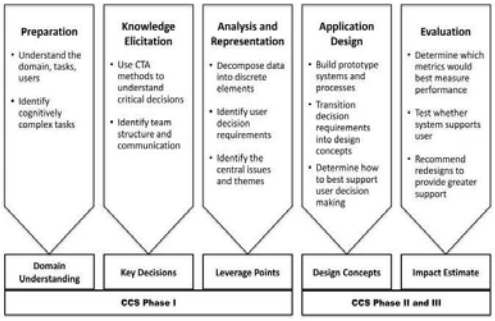

Fig 2. Five phases of Cognitive Systems Engineering. Adapted from [6]

knowledge about human cognitive performance, such as what is needed to attract attention to unexpected data, into principles and techniques to develop solutions including human-computer interface design. [7] Integration of these five phases ensures that the solution this process produces is grounded in data that are drawn from study of the clinicians and BICU work setting (is ecologically valid). It will also help the team to anticipate shifts and unintended consequences that can happen when new IT such as the CCS is introduced [8].

CSE activity in the first year included preparation and knowledge elicitation through interviews, surveys, and artifact analysis, as well as analysis and representation using table and diagram development and thematic analysis. During the first two years of this project, the team identified 20 key challenges and barriers to cognitive work on the BICU, then translated them into concise problem statements and 39 information system requirements, developed representations to describe the BICU environment and key resources that clinicians use there, formulated a use cases to describe to developers how the system is intended to work, and developed a descriptive model of Burn ICU cognitive work (Figure 3).

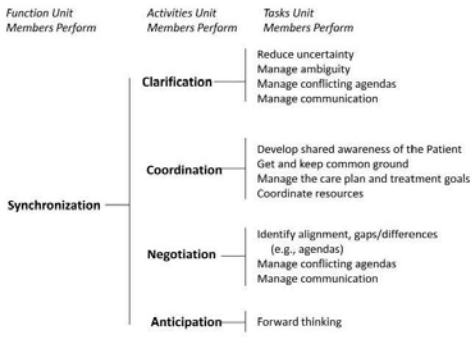

Fig 3. Model of BICU cognitive work

As we reported in Nemeth et al [9] complexity can hide underlying systematic patterns in cognitive work. Figure 3 illustrates these patterns in the BICU. Synchronization of patient care among clinicians and over time is the unit's mission, and is shown at the model's the top level. All of the activities that unit members perform to synchronize care are at the next level: clarification, coordination, negotiation, and anticipation. Supporting tasks from reducing uncertainty to forward thinking comprise the model's activities. Each task can be accounted for in the way that clinicians interact with each other and use information sources to minimize uncertainty. Requirements that the team developed from these tasks indicate opportunities, or leverage points, to improve synchronization.

The team is now programming the user interface and data mining functions based on Year One findings, and is developing increasingly refined prototypes that we evaluate with BICU clinicians at each stage through agile software development methods. Evaluation, including usability assessments, will verify improvements to decision making that result from clinician use of the CCS.

IV. FINDINGS

Each of the CCS features fulfills one or more of the system requirements. This ensures that each aspect of the CCS will enable clinicians to overcome barriers and uncertainty about patient and team status to make better-informed decisions about diagnoses and treatment. Three aspects of the project are geared to help clinicians find and use salient information:

- Core functions, including data views
- The ability to personally configure displays
- Data mining, to reveal trends and patterns.

A. Core Functions

Six basic elements comprise the CCS, which are essential to support the BICU cognitive model (Figure 3).

- *Unit View.* Organized as a BICU floor plan, the view includes an identifier for each patient, status of planned tasks, and facilitates resource allocation and prioritization, care planning and coordination. Each occupied room includes a *Patient Identifier:* a graphic element that includes patient number, total burn surface area at admission, an indicator of illness severity and progress based on key trends. The identifier enables the BICU staff to scan among and across patients and recognize care needs at a glance.
- *Patient View.* Figure 4 depicts the early design for how all critical data are shown for an individual patient, organized by system from cardiac and neurological to wound care and infectious disease using a "parent-child" tab/window format. In contrast with the current EHR shown Figure 1, the Patient View presents all salient, data related to the patient in a single window.

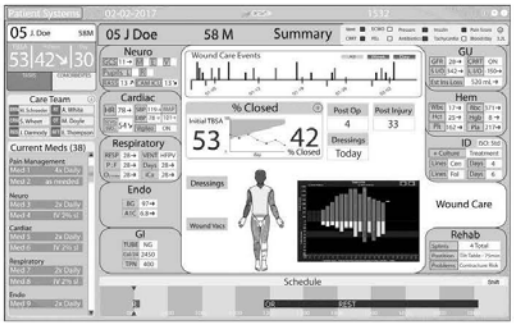

Fig 4. Information design of Patient View. *Copyright © 2015 Applied Research Associates, Inc.*

- *Scheduling.* Staff assignment to the unit, and to each patient care team, improves unit efficiency by making opportunities for care evident. It also saves "missed" opportunities for care such as a chaplain visit, or rehabilitation.
- *Order Management.* The view lists all orders from treatments to diagnostic tests, to minimize uncertainty about diagnostic and therapeutic plans, status, and results. BICU staff members currently spend a significant amount of cognitive and physical energy to coordinate, account for, and adjust medications, therapies, and investigations. The CCS displays information on these items in a manner that makes it easier for care team members to review, question, and modify.
- *Checklists.* An interactive roster of quality measures makes it possible for the unit's Charge Nurse to ensure in real time that essential evidence-based care is accomplished. The checklist view provides a way for the CCS to track quality measures and items may be identified from data in the EHR. For example, possible shortcomings or "faults" can be pushed to clinicians, or items may be displayed as clinical reminders for clinicians to use when making decisions.
- *Tasking, Messaging, and Alerting.* Real time message correspondence among care team members supports the development and maintenance of common ground regarding their patient's history, status, prognosis, and care plan. It will keep the healthcare team connected to important information and to each other. This feature combines rules related to tracking information and clinician activity and providing push notifications ("alerts") according to changes in information or at the request of team members.

B. Configurable Displays

The Patient View can be configured, so that a clinician can change what is displayed and how it is shown on the screen. Salient information is available and evident, because views are based on role and task requirements. A configurable display means a resident does not need to review information other than what she/he needs to prepare for morning interdisciplinary rounds. Clinicians who prefer to see certain variables displayed graphically can choose to see them in a stacked line graph. Others who prefer to see the same variables in numeric form can choose to have them displayed in a table. This also makes the creation of relational information displays possible. Such a display shows meaningful combinations such as a "cardiovascular," "cardiopulmonary," or "cardio-renal" that may help clinicians answer questions about patient condition or treatment effects. This ability to choose information and its display is expected to improve clinician understanding of patient trajectory.

C. Machine Learning

Machine learning (ML) makes it possible to identify patterns such as trends, comparable patients and care regimens, and metadata on how clinicians use the system. The project's ML effort combines the use of traditional (open-source off-the-shelf) data mining tools with innovative new data mining capabilities. This dramatically improves clinician ability to quickly identify and view similarities/discrepancies between a current patient's health trajectory and those of a large database of previous patients. Clinicians can make more informed decisions about patient care because they can leverage knowledge of the treatment plans and results from all available records of previous patients on the unit who have had comparable conditions and interventions.

We see two major technical challenges for ML:

1) *Irregular Time Series.* Patients have a wide diversity of time-series data which represents a sequence of condition states, medical interventions, and patient responses. Entries in the health records are sparse and uncertain. This complexity makes it necessary to develop a solution that incorporates temporal models that will show progressions of care and sensor readings in context.

2) *Scale and Performance.* The ML operations must provide quick and accurate responses at scale. The system will consider many patients dating back many years and regularly ingest new patient records over time. Some will have records spanning long time periods. The problem's scale requires a solution that will handle this large existing database. It needs to accept, integrate/index, and classify new data from ongoing patient care, quickly identify best matches to support interactive queries from clinicians, and probabilistically project possible future trajectories based on historical precedence.

The CCS project uses eight ML components to analyze clinical records, develop models of patient/clinician interactions, and provide clinicians with decision-support information using the CCS user interface.

- *Data Exploration.* Analyzes the patient database schema and contents and extracts summary metadata and pre-processes key data from historical patient records for cleaning and staging for analytics.
- *Data Access Layer.* Cleans, restructures, stages, and updates data for ML analytics without modifications to the source medical records. Storing cleaned data in our own schemas enables faster data access for analytics.
- *Element Analytics.* Reads in time series patient data and write out aggregations, interpolations, and performs direct data and trend analytic functions (e.g., Sequential Organ Failure Assessment (SOFA) scores).
- *Sequence Analytics.* Uses ML to model temporal sequences where the ordering and relationship of events is critical to interpretation and similarity measures. (e.g., Event Sequence Alignment and Clustering). Identifying sequences of events that are similar between the current and set of historic patients, we identify cohorts and support case-based predictive analysis of possible future events.
- *Similarity Analytics.* Computes correlations within and across multiple factors in the data (including aggregated data) over time windows, and learns models for identifying salient factors for cohort similarity. We use an ensemble of similarity calculations to capture different ways in which temporal values can be similar.
- *Semantic Analytics.* Bridges the semantic meaning of various unstructured data fields to identify domain-knowledge-based similarities where content-only comparisons fail. (e.g., integration of SNOMED CT or ICD-9/10 ontologies) This is useful for identifying key clinical events from notes data in the patient record.
- *Real Time Analytics.* Directly supports interactive features of the UI through analytic capabilities (e.g., moving and windowed averages), and running of models against active patient data (e.g., extracting clinically relevant similarities from cohort recommendations).
- *Metadata Analytics.* Instruments the various components of the CCS system so that we can measure performance, assess usage, identify issues, and better estimate scalability and stability.

The ML function is being developed, and will be evaluated in parallel, with the CCS user interface.

V. DISCUSSION

Automation has traditionally been used in high risk settings to replace individuals in the performance of work that is considered to be inappropriate for humans. Rather than replace humans, though, automation needs to *aid* humans as they work to solve problems.

The way that a problem is presented can improve or degrade the performance of cognitive work. Expertise in healthcare is the ability to know what is—and what is not— important [10]. Aiding has typically been directed at the novice level [11], but it is actually most needed on *difficult* problems. Difficult problems are the type that experts confront. This is also true in other high risk work settings in addition to healthcare.

Healthcare activities rely on the acquisition, portrayal and analysis of therapeutic and diagnostic information as an integral part of individual patient care. The daily work of the clinician requires representations that serve as a representation of the work that changes continually and must be managed successfully in order to accomplish goals [12]. The information that is represented, and how it is represented, depends on the individual and group cognitive work that it is intended to support. Individual elements of information vary widely in the length of time that they remain reliable. Their salience depends a great deal on their context. The need for accurate, timely information exists at the level of the entire unit as well as at the individual clinician level. The unit level is where the technical work of unit planning and management directs who will get care, what type of care will be provided, and when it will be provided.

Actual improvement to support patient care relies on going beyond the surface descriptions (phenotypes) of work domains to reveal and understand the underlying patterns (genotypes) of systemic factors [13]. Human factors [14] and CSE research methods within the naturalistic decision making model [15] have proven value in revealing the key aspects of healthcare work domains to develop valid IT systems and information displays.

VI. SUMMARY

In order to succeed, IT support for healthcare cognitive work requires repeated, deep looks into the clinical work setting using methods that are suited to the study of individual and team cognitive work in order to find what data truly matter. Use of CSE's decision-making approach to understand patient care settings can inform the development of effective EHRs. The salient information display that results can begin to overcome embedded difficulties with current health records.

Clinician information needs change according to patient condition, patient problem, clinical task, and clinician role and experience. Through CSE, we have identified seven core functions for the CCS health IT system that will support clinical decision making and communication needs. By matching needed information to diagnostic and therapeutic tasks, the CCS decision and communication support tool is ecologically valid (matches the work domain) and, as a result, is inherently useful.

More efficient, reliable collaboration among members of the ICU staff who use the CCS is expected to improve patient safety and optimize patient outcomes. Readily using salient information will spare clinicians wasted time, uncertainty, and indecision. We expect this will also help to decrease missteps, lapses, delays in car, resulting in shortened length of stay, reduced cost of care, and improved patient safety.

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