Final Progress Report

Title: Understanding Primary Care Teamwork in Context: Implications for HIT design

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Organization: The Board of Regents of the University of Wisconsin System

Dates of Project: 09/30/2014-09/29/2020

Federal Project Officer: CDR Derrick L. Wyatt

Funded by: Agency for Healthcare Research and Quality

Grant Award Number: R01 HS022505

1. Structured Abstract

Purpose: To determine the cognitive needs of primary care physicians and their teams and use these to design and test an electronic health record (EHR) prototype supporting their needs.

Scope: The project focused on clinicians and staff at eight primary care clinics in the Midwestern United States to determine cognitive needs; later clinicians from four clinics gave feedback on the EHR prototype.

Methods: Goal Directed Task Analysis (GDTA), consisting of clinic surveys, observations, interviews and a detailed data analysis process, was used to understand the cognitive needs of primary care clinicians and staff caring for adult patients. We developed the EHR prototype using an iterative process of whole-team in-person design sessions and small group design with large group feedback. We made further prototype changes to end user feedback from testing sessions.

Results: We created two GDTA maps, a physician/advanced practice professional map and a nurse/medical assistant map, with the cognitive needs of these clinicians. From these maps we developed, de novo, a 16-page EHR prototype in prototyping software. The prototype includes the front end of a patient chart with a care plan-based design and additional functionalities to coordinate schedules, tasks, and other information across team members. Extensive user testing provided more than 900 user comments, 95 of which resulted in our team making design changes. Specification documents provide documentation for all aspects of the design.

Key Words: Goal Directed Task Analysis, Cognitive Work, Primary Care, Teamwork, Electronic Health Records, Situation Awareness, User Interface Design

2. Purpose

The project had two specific aims. *Specific Aim #1* was to identify the cognitive work requirements of primary care clinicians and teams. We used a cognitive task analysis technique, Goal Directed Task Analysis (GDTA), to determine the cognitive needs of primary care physicians (PCPs) and advanced practice professionals (APPs), nurses and medical assistants (MAs), and other primary care team members working with them in the clinics to care for patients. This involved observations and cognitive interviews across eight clinics and an extensive data analysis process to create GDTA maps outlining situation awareness needs. Deliverables from this aim are two GDTA maps: (1) PCPs and APPs, and (2) nurses and MAs, which represent the cognitive requirements of primary care clinicians and teams to be supported by electronic health records (EHRs).

Specific Aim #2 was to develop and test specific EHR interface design requirements. Through a series of in-person and online design sessions, our team created EHR-interface design recommendations based on the results of Aim 1. We then performed end-user testing of an EHR prototype with a sample of primary care clinicians. The feedback they provided was used to modify the design during and after testing to develop our final EHR prototype. The deliverables from this aim are the EHR prototype and accompanying specification documents which show the (1) data elements (e.g., labs results or problem lists), (2) data formats (e.g., narrative, discrete numerical value or graphed trend), and (3) data integration recommendations to input and/or display for a new EHR interface that supports primary care cognitive work.

Our initial goal was to evaluate cognitive work requirements for PCPs and teams centered on supporting adult patient visits. We focused on primary care core teams[1], which we defined as a physician and/or APP, and their nursing staff (both nurses and MAs) who work closely with that physician/APP to care for patients. We further expanded this team to include other patient care clinicians and staff supporting the core team, such as front desk staff, educators, pharmacists, social workers, and case managers. In defining our scope of work, it was also critical to extend beyond the current paradigms of patient care and teamwork to avoid constraining our GDTA and ultimately the EHR design. While our initial scope aligned with supporting patient visit-related work, we found that this is an evolving paradigm also including electronic or telephone visits and it did not account for patient information available in between visits and monitoring of the patient status to ensure patients are receiving the appropriate health care and achieving the intended outcomes, which are inputs to and aftercare required after visits. We also expanded our scope to include the cognitive needs for all team task management and work scheduling as these needs directly impact team composition and teamwork expectations that then impact patient care.

3. Scope

Background

Primary care, the foundation of US healthcare, is highly utilized and highly complex.[2] Primary care requires a sustained partnership between clinicians and patients, functioning as the patient's medical home and first point of contact for problems.[3] Primary care physicians (PCPs) deal with 3-7 problems per patient visit.[4,5] To coordinate a panel of Medicare patients over 1 year, a typical PCP deals with 229 other physicians from 117 practices, and a typical Medicare patient sees 7 different physicians in 4 different practices.[6,7] It is no surprise that patients report receiving disorganized and inefficient care, especially when transitioning between physicians, or after hospitalization.[8] As the population ages, primary care utilization and complexity will increase.[4] PCPs are facing growing pressure to deliver more and higher quality care to their patients in the standard 15 minute visit - an impossible feat without significant assistance.[3,5,7,9,10] This pressure also leads to more chances for diagnostic and therapeutic errors,[11] suboptimal patient outcomes including preventable and ameliorable medication errors and adverse drug events,[12-14] and poor physician outcomes such as job stress, burnout, early retirement.[15] Clearly change is needed in primary care to help clinicians deliver high quality care in a comprehensive, coordinated, and efficient manner.

The Patient Centered Medical Home (PCMH) model is a team-based model of care endorsed by more than 500 professional and business organizations as the new model of primary care delivery.[16] A key component of the PCMH is the implementation of organized care teams in the primary care clinic.[17] PCMH teams include physicians, advance practice nurses, physician assistants, nurses, MAs, pharmacists, nutritionists, social workers, educators and care coordinators, working together to deliver care. Health IT, and more specifically the EHR, is one of the foundational supports of the PCMH model. Health IT collects, stores, and manages personal health information; aggregates data to improve processes and outcomes; and supports communication, clinical decision making, and patient self-management. But PCMH demonstration projects revealed that EHRs, often designed for hospital systems, did not adequately support primary care practice and teamwork needs.[18-20] Additional studies of primary care work and EHRs confirm these findings.[21-27]

This project focuses on primary care clinicians and teams to support efforts to transform primary care into the PCMH model. The PCMH model needs EHRs that support primary care clinicians and teams, but, developing these EHRs requires scientific evidence on which to base design. Little attention has been given to designing EHRs that support the collaborative work of interdisciplinary teams of clinicians. This challenge was clearly highlighted in an Institute of Medicine (IOM) report on health IT and patient safety.[28] EHR research linking EHR use to high quality, low cost care in primary care has shown mixed results in improving receipt of care, e.g., preventive and chronic disease care, minimal evidence for improved patient outcomes and safety,[29,30] and no savings in administrative or total costs.[31] EHRs have been associated with poor consistency across system design, poor usability, and poor fit into primary care workflows.[32-34]

The Federal Administration committed $48.8 billion in funding for health IT as part of the HITECH Act[35] including $17.2 billion in the form of incentives for physicians and hospitals to adopt EHRs if the physicians become "meaningful users" of the EHR as defined by the Office of the National Coordinator for Health IT (ONC).[36] Yet the director of the ONC stated in an article on EHR adoption, "Many certified EHRs are neither user-friendly nor designed to meet HITECH's ambitious goal of improving quality and efficiency in the health care system."[37] A survey of primary care physicians in 2012 found that less than 10% could meet meaningful use criteria.[38] Karsh et al., in a seminal paper on health information technology fallacies and sober realities state, "This mismatch between the reality of clinical work and how it is rationalized by health IT leads clinicians to perceive that these systems are disruptive and inefficient. Accommodating the non-linearity of healthcare delivery will require new paradigms for effective health IT design."[39] Our proposal provides one such new paradigm by using cognitive and team work analysis to specifically address this gap. Our study contributes evidence for how to design EHRs to support clinician cognitive work, which is, (1) an important step toward demonstrating that EHRs can be safe and effective, and (2) a critical part of making physicians and other primary care clinicians *want* to use them to their full capability when they are implemented.

In human factors engineering, "cognitive work" refers to the cognitive processes used toward goal-directed work.[40-44] Examples of cognitive work include information seeking, situation assessment, decision making, response selection and execution, coordination, communication, error recovery, problem identification, and problem solving. The design of IT interfaces affect user performance.[45-47] The abundant design problems in EHRs in primary care go well beyond simple usability fixes. Solutions to complex design problems must not be confused with improved usability of existing EHRs.[48] Furthermore, there still exist questions of (1) what to display, (2) with what other data to display it, and (3) in what form (discrete value, trends, or status)? Usability design is critical, but only after addressing those three questions.

To address design problems, we propose, requires cognitive task analysis methods.[49] These methods seek to achieve two reinforcing goals: (1) understanding the fundamental cognitive work requirements of the work domain; and (2) understanding how current practitioners respond to the demands of the domain.[50] We use Goal Directed Task Analysis (GDTA)[41] which is specifically designed to determine cognitive work requirements in order to design information technologies (IT) that support these requirements. The goal of GDTA is to develop IT that provides high levels of situation awareness (SA) for users by giving them the information they need and having them input the right information. SA can be thought of as "what must be known" in order to complete cognitive work.[41] In primary care this would mean having EHR interfaces that (1) request meaningful information for the clinicians to enter and (2) display the correct information for clinicians to produce quick, accurate, and complete understanding of what is happening with their patients. What is specifically innovative about GDTA is that it (1) focuses on goals, not tasks. Goals are cognitive requirements; tasks are cognitive or physical activities that serve goals. This is important because in primary care, clinicians do not enter patient encounters to accomplish specific tasks; rather their work is driven by goals (e.g., address the patient's problems, make the patient healthier or feel better, diagnose the problem, determine appropriate treatments). Depending on the goals, tasks may be carried out in any number of sequences. Therefore, flow charts which represent normative sequences of tasks are not useful to understand how to design technology for complex cognitive work like that which occurs in healthcare.[49,51] GDTA allows for a non-linear representation of primary care work that can occur in any sequence depending on the relative importance of different patient care goals.

We assembled an interdisciplinary team of researchers including physicians, human factors engineers, and research staff with expertise in IT design, sociology, public health, and nursing for this federally funded project, extending beyond the typical single person or small team of GDTA experts.

Setting & Participants

Specific Aim #1: Identify the Cognitive Work Requirements of Primary Care Clinicians and Teams

Eight primary care clinics located in the Midwestern United States were recruited through a research partnership with the Wisconsin Research and Education Network (WREN), a practice-based research network. Interested clinics responded to general recruitment emails and to direct inquiries for participation from WREN staff.[52,53] To maximize generalizability, we recruited a purposive sample of primary care clinics with team-based care that varied based on clinic and staff characteristics including 1) location (rural, urban, suburban), 2) clinic specialty (family medicine, general internal medicine), 3) current EHR vendor, 4) presence of learners/resident physicians, 5) academic affiliation (academic, community, academic-affiliated), 6) core team make-up (nurse or MA), 7) clinic ownership/governance (physician-owned, hospital or health system owned, federally qualified health center), 8) clinic building location (freestanding clinic, located within multispecialty clinic setting, located within hospital system), 9) physical presence of various other team members in the clinic (see below), and 10) the presence of onsite ancillary services, e.g., lab, imaging, social services.

Clinics were required to have two physician-led teams interested in participating in the study observations and interviews. A team, or "core team", consisted of a primary care physician, the APPs working with them, and their immediate care teams of nurses and MAs who worked with them to perform supportive tasks for patient visits, e.g., rooming patients. Ideally these teams were permanent teams such that they typically work with each other on a day to day basis for patient care. Additionally, other team members that supported the core team members' work were invited to participate in less intensive observations and interviews. These included social workers, pharmacists, health educators, receptionists, schedulers, registrars, behavioral health specialists, chronic care coordinators, and imaging and lab technicians. WREN staff and the research team held a research kick-off meeting with each clinic prior to the start of data collection to answer questions and share study information sheets with clinicians and staff. Clinics were paid $4500 for their participation.

Table 1 provides a summary of the clinic characteristics. Seven different EHRs were in use across the participating clinics including Epic (3 versions), Cerner, athenahealth, Intergy, Practice Partner, Meditech, and eClinicalWorks. A summary of participants involved in the GDTA observations and interviews, their job titles, and their presence across clinics is provided in Table 2. An additional 10 clinic managers/administrators across 8 clinics participated in the clinic survey questionnaire and interviews.

Specific Aim #2: Test Specific EHR Interface Design Requirements

A convenience sample of clinics and clinicians were chosen as end users for testing of the EHR prototype based on clinician interest and research team scheduling ability. Clinics were paid $1000 for their participation.

4. Methods

Study Design: Designing for Situation Awareness

Situation awareness is a critical aspect of cognitive work and decision-making in complex environments, such as healthcare.[54] SA is defined as "the perception of the elements in the environment within a volume of time and space (level 1 SA), the comprehension of their

Table 1. Primary Care Clinic Characteristics

	# of clinics	% of clinics
Total	8	100
Location		
Urban	2	25
Suburban	2	25
Rural	4	50
Ownership model		
Hospital or health system	4	50
Physician owned	3	37.5
Federally qualified health center	1	12.5
Physician Residency Teaching Site		
Yes	1	12.5
No	7	87.5
Number of physicians/APPs in clinic		
1-5	1	12.5
6-10	2	25
11-20	3	37.5
21-30	2	25
Specialty		
Family Medicine	6	75
Internal Medicine	2	25
Primary Care Clinic type		
Freestanding	3	37.5
Located in building with other clinics	5	62.5

Table 2. Goal Directed Task Analysis Interview and Observation Participants

Job title	# Participants	# Clinics with role (%)
Physician		
Family Medicine	10	6 (75)
Internal Medicine	4	2 (25)
Advanced Practice Professional		
Nurse Practitioner	2	2 (25)
Physician Assistant	3	3 (37.5)
Nurse	18	8 (100)
Medical Assistant	17	6 (75)
Scheduler/Receptionist	17	8 (100)
Health Educator	6	4 (50)
Behavioral Health Specialist	3	3 (37.5)
Pharmacist	3	3 (37.5)
Imaging Technician	2	2 (25)
Lab Technician	2	2 (25)
Social Worker	2	2 (25)
Clerk	2	1 (12.5)
Nurse Case Manager	1	1 (12.5)
Nursing Supervisor	1	1 (12.5)
Chronic Care Coordinator	1	1 (12.5)
Billing Specialist	1	1 (12.5)
Total	94	-

meaning (level 2 SA), and the projection of their status in the near future (level 3 SA)."[54] People rely on SA to make sound decisions to achieve their goals. This model of information processing is a central basis for effective decision-making, especially within complex and dynamic systems.[54] Team members' mental models must also align in order to effectively collaborate and coordinate interdependent activities towards a larger team goal (Figure 1). Team SA is "the degree to which every team member possesses the SA required for his or her responsibilities"[54 (p. 195)] Shared SA, or the extent that team members have the same SA requirements, is critical for a cohesive understanding of current states and overall team coordination.[54] Despite the importance of SA and shared SA to effective decision-making and teamwork, existing tools to define cognitive work and inform the design of health technology are limited in their ability to capture this aspect of cognition, with the exception of GDTA.[54]

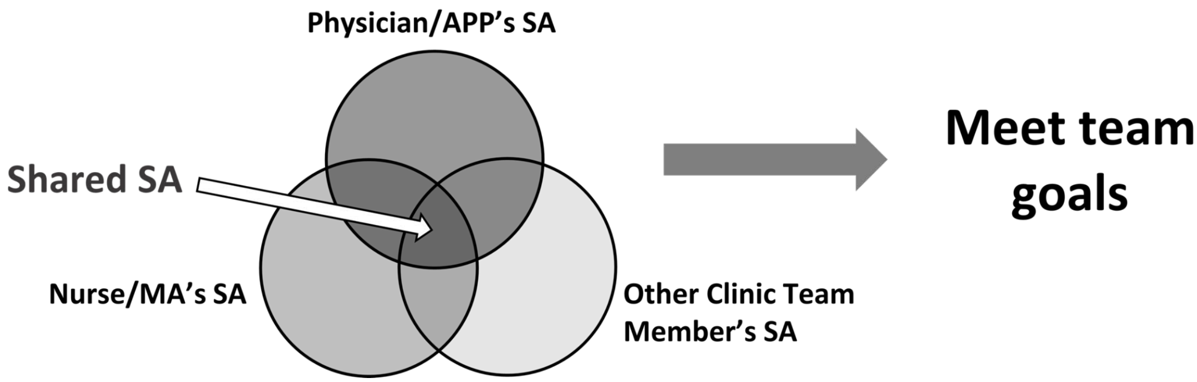

Figure 1. Team Situation Awareness in Primary Care

Data Sources / Data Collection

Specific Aim #1: Identify the Cognitive Work Requirements of Primary Care Clinicians and Teams

<u>Overview of Data Collection & Analysis</u>

Figure 2 provides a summary of our rigorous methods for data collection and analysis

<u>Domain Analysis</u>

Domain analysis informed our understanding of primary care in preparation for observations and interviews. Academic and grey literature were reviewed on the roles and responsibilities of primary care team members, primary care clinic team structures, and previous primary care task analyses.

<u>Clinic Survey, Clinic Tour & Clinic Manager Interview</u>

Research team members toured the primary care clinic facility with the clinic manager to better understand the environment of care and ancillary services available. Clinic managers also participated in a survey questionnaire regarding clinic and patient characteristics which included a follow-up interview to better understand clinic, role, and team structures; staff schedules and job duties; and tools and health IT used to support work.

<u>Observations</u>

To better understand primary care team goals in context, we completed a 2-4 hour observation with each member of the core team and most of the other patient care staff, shadowing them as they performed their work. Trained observers used an observer guide to record detailed notes on work tasks, teamwork, communication, and use of technology. No identifiable patient data or protected health information was collected. Observers followed our IRB-approved code of conduct, which requires them to be neither intrusive nor interrupt. Information sheets were reviewed ahead of the observations and participants were allowed to opt out of the study or that day's data collection for any reason. A minimum of five patient care visits and the work outside of visits, for example, pre-visit work such as chart review and prepping and post-visit work such as visit documentation in the EHR were observed. As the study focused on the care of adult, non-pregnant patients, pediatric and obstetric related visits were not observed. Patients were informed about the study by the nurse, MA or other clinic staff member who brought them to the examination room and patients were allowed to opt-out of having their visit observed. Tandem observations of teams, in which two researchers independently shadow two members of the care team at the same time, for example, one researcher observing the physician while the second researcher observed their nurse or MA who was rooming patients, allowed observation of core team shared work.[55]

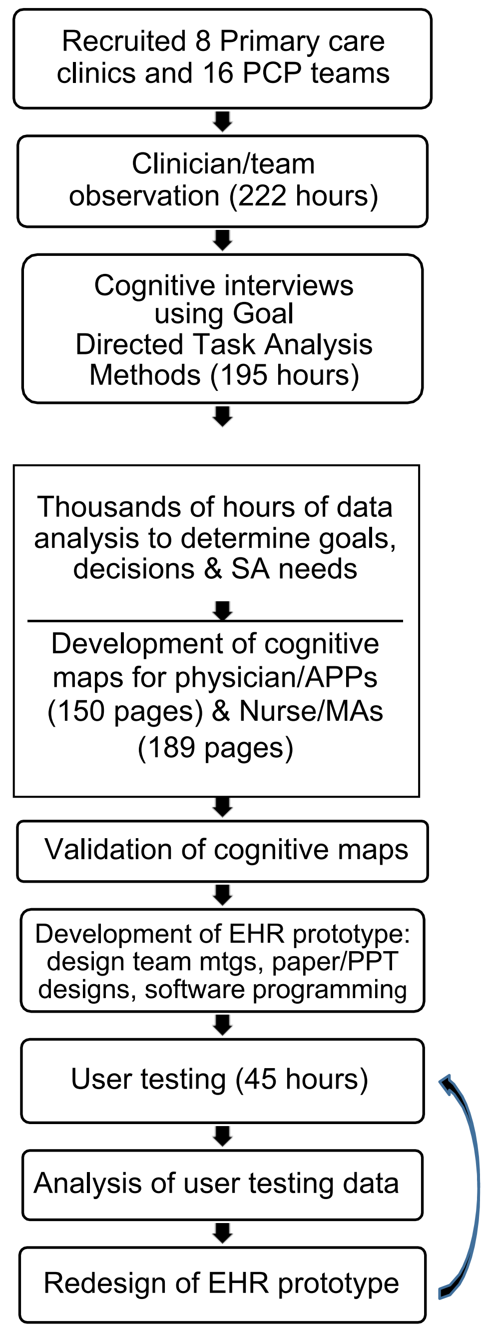

Figure 2. Summary of Rigorous Methods

<u>Interviews</u>

Semi-structured GDTA interviews of individuals were conducted by trained two-person teams, audio recorded and transcribed. Core team members participated in 3 interviews and other team members participated in 1 interview. Each interview lasted 1.5 hours with physician/APP and MA/nurse team interviews occurring concurrently with two interview teams to fit within practice schedules. Participants first described their high-level goals in caring for patients. Probes and follow-up questions and were used to determine sub-goals required to meet the high-level goals and decision-making needed to carry out each subgoal. For decisions, participants were asked about information they needed and the assessments that they were making, corresponding to level 1, 2, and 3 SA to make that decision. Participant observations and the clinic survey were used to identify goals and tasks that were not yet discussed by the participant via their recollection of the work they do. In addition, when participants discussed teamwork and completion of goals and tasks across team members, we used this information to ensure team tasks were discussed in both physician/APP and nurse/MA interviews. Participant information about education, length of practice, role on the team and who they identify as their team members was also gathered.

<u>Goal Directed Task Analysis Mapping and Iterative Data Collection & Analysis</u>

The study's application of GDTA to understanding primary care teamwork in context was based on published descriptions.[54,56-58] Classic GDTA is comprised of five steps, with iteration between steps. We adapted the method based on supporting scientific research rigor in data collection and analysis in a primary care context. Descriptions of each step and our adaptations are provided.

A GDTA map is a visual representation of the goals, subgoals, decisions and information needs, without focus on how that information is obtained by participants or how tasks are completed.[54 (pp. 63-68)] Each map summarizes the cognitive work within a specific role. As originally devised,[54 (pp. 63-68)] the process of GDTA mapping requires interviewers to meet as soon as possible after each interview to discuss new information and use it to build the map. With multiple interviewers, this process was challenging logistically. We started the mapping process by creating maps using interview data concurrent with clinic 1 data collection. After interviews we met as a group and used our notes to begin the mapping process, outlining goals, subgoals, decisions and level 1, 2, and 3 situation awareness needs. Interview transcriptions were reviewed by the team and compared with the map and any omitted information was added. Thus at the end of data collection at clinic 1 we had early draft versions of a physician/APP map, MA map and nurse map. The process of immediate mapping followed by transcript review and map revisions weeks later was laborious. In addition, having multiple interview teams collecting data at the same time led to data overload and issues with immediate and concurrent mapping. Therefore we adapted our methods and focused only on data analysis through transcript review for the later clinics. We developed a coding structure of 20 topic codes that represented different goals and domains of work being completed from our draft GDTA maps, e.g., preventive care, chronic care, or teamwork. One research team member then deductively coded each physician, APP, nurse and MA interview from clinics 1-4 using these codes. A second coder reviewed and the verified initial coding. We then reviewed all excerpts on each topic, and teams of 3-5 researchers met to build the information into the GDTA map structure. Thousands of hours were spent by team members in the GDTA analysis process.

We made the decision to combine the physician and APP roles into one map given the very similar roles performed in the clinics. In the same manner, we combined nurses and MAs cognitive work into one GDTA map recognizing that nurses and MAs were performing similar work across the clinics but which varied by the depth of involvement. For example, while triage of patient symptoms is typically thought to be nurse work, some MAs were performing basic triage of patient symptoms in order to collect information and determine the level of urgency of the call and a disposition. Both MAs and nurses performed patient rooming tasks and visits.

After data collection at 4 clinics, the team recognized the same goals and tasks were being discussed with few new goals and tasks at clinic 4. We then moved to a data validation process in which pieces of the maps were presented to participants at Clinics 5-8 and were used to validate the existing map and probe data omission during the interview process. New data were added to the map after team discussion. To ensure consistency and rigor in how information was used for mapping, we conducted immediate debriefs following each interview, in which the interviewers made detailed notes about the new information they learned about goals, subgoals, decisions and information needs, including where in the current GDTA map the information could be added. Debriefing note review ensured that no information was missed. Data saturation was reached with clinic 8 data collection.

Specific Aim #2: Test Specific EHR Interface Design Requirements

<u>Prototype Development</u>

The research team employed rigorous prototype design methods to ensure that the GDTAs were appropriately translated into the prototype and that design decisions were vetted by the research teams. We developed the EHR interfaces (data displays and inputs) designed to support situation awareness and decision-making of PCPs and their teams, thus addressing the deficiencies of existing EHR designs, using situation awareness-based design principles.[54]

We evaluated seven prototyping software products and chose JustInMind software (www.justinmind.com) to best meet our prototyping and testing needs. Using human factors design principles, we started the design process with the look and feel of our prototype, selecting font, color, and text sizes with high usability, then created standard widgets for use in the prototype. Our color scheme was rigorously tested to ensure maximum ability to discriminate colors in color-blind and typical-sighted individuals. A total of 5, 3-day research team design sessions were held during which the entire research team (12-15 persons including practicing primary care clinicians, and experts in human factors engineering), led by Dr. Mica Endsley, made major decisions about the EHR prototype design. Our team reviewed the GDTA maps and embarked on prototype design starting with high level structure and functions and then working down to page level design while following situation awareness design principles.[54] We developed paper prototypes during design sessions that were then turned into PowerPoint designs to simulate the EHR prototype design, which was followed by programming that design into our working prototype. In between design sessions we held weekly team teleconferencing sessions to share designs, receive feedback and build consensus on final designs. Widget and page designs were reviewed by our executive design team comprised of Drs. Endsley, Wetterneck, Beasley, Smith, Wiegmann and Ms. Cartmill for final approval. We completed an iterative process of design with constant feedback from the same expert team as the designs were fully developed into a functioning prototype. This process progressed over 3 years.

End User Testing and Feedback

We developed multiple patient scenarios to fill our prototype with realistic patient examples, and 16 end user testing scripts covering a high-level system overview and the 13 pages and 2 functionalities in the electronic prototype that were ready for testing at that point in time (three pages were completed after user testing). Pilot testing of scripts was completed. A convenience sample of physicians and APPs (8) and nurses and MAs (6) from 4 clinics participated in 60- to 90-minute testing sessions. Participants completed brief surveys at the end of each reviewed page and at the end of the testing session regarding the all pages reviewed in the session. Questions were adapted from the System Usability Scale[59] and rated on a scale of 1-7 (strongly disagree – strongly agree). Sessions were recorded in Camtasia to record both audio and video of the display during testing. Extensive notes were taken during the sessions to record user comments about user design features and answers to questions about design features. From these notes, discrete user comments associated with the EHR page being tested and the feature or question to which the comment pertained were compiled and placed into a Microsoft Excel spreadsheet. The research team adjudicated each comment and came to agreement on a recommended disposition of 1) no change, 2) watch for further feedback on this topic, or 3) redesign. Comments were also designated a valence of either a positive comment or negative comment about design when possible.

Limitations

The major limitation of our project is generalizability of our cognitive work requirements to primary care in the United States and beyond. Our original data collection was planned for 10 clinics of a diverse nature in the Midwest to minimize this. Resources allowed collection at 8 sites however we believe we reached saturation of data by clinics 5 & 6. Secondly, we originally planned to create separate Nurse and MA cognitive maps thinking their cognitive requirements differed greatly. However, we found there was much overlap in functions across the different clinics so combined map was made. Next, while our prototype underwent extensive user testing for feedback on design, due to prototype limitations, we were not able to perform the situation awareness-based usability testing required to prove that our new designs improve situation awareness and decision-making in primary care. Last, the cognitive requirements are specific to primary care clinicians and their teams; there use in other subspecialties or by other clinicians has not been evaluated. However, many of the cognitive requirements determined for primary care clinicians and teams could be translated to problem specific care delivered by subspecialists.

5. Results

Principal Findings

Specific Aim #1: Identify the Cognitive Work Requirements of Primary Care Clinicians and Teams

Goal Directed Task Analysis

Cognitive work requirements were determined based on data collection with a sample of 103 clinicians and staff across 8 primary care clinics for 222 hours of observations and 195 hours cognitive interviewing. Thousands of hours of data analysis were undertaken to develop two GDTA maps with cognitive work requirements: a 150-slide physician/APP map and a 189 slide nurse/MA map. The data collection and analysis process took were completed over 2 years' time.

During our first design session with the research team, the team created a list of insights from the data analysis regarding key roadblocks to achieving situation awareness that supports decision making in primary care. We were determined to overcome these challenges in the EHR prototyping process. Table 3 lists the roadblocks, which were related to EHR design, user-EHR interaction and user and clinic system issues.

Table 3. Situation Awareness Roadblocks in Primary Care

- Poor quality and missing information
- Slow, inaccurate, or missing feedback and tracking on the effects of actions
- Little support for creating higher levels of SA (understanding and projection)
- Poor data integration and organization
- Lack of information on trustworthiness of data
- Inadequate task and decision support
- Information sensitivity affecting the recording and viewing of information
- Missing or inconsistent patient follow-up
- Inadequate support for care outside of office visits
- PCP and team information and work overload
- Poor information and task sharing across team
- Technology interference in patient, clinician and team interactions

Specific Aim #2: Test Specific EHR Interface Design Requirements

End User Testing of Tandem EHR Prototype

Fourteen end-users from 4 of our participating clinics completed 31 user testing sessions (1-3 sessions each). All participants completed the high-level overview. On average each page/functionality was reviewed by 6 participants (range 2-9). In total 907 user comments about the prototype were recorded (mean: 29 comments per session, range: 11-42). Results of the user testing sessions were overwhelmingly positive about the user interface. Over 700 comments were adjudicated as 'no change.' Most of these were positive comments about features users liked about the prototype or how it would improve their current work and fix current problems. Ninety-five comments resulted in design changes to the prototype. The team followed our typical design process described earlier for design changes. As the user testing, review of user comments, and design changes occurred concurrently, many of the new designs underwent subsequent testing in future sessions. Table 4 shows end user survey results of the overall system at their last user testing session.

Table 4. End User Testing Survey Results: Overall System

Question*	Mean	SD
It would be easy to navigate around the user interface.	6.0	0.47
The user interface is designed with me in mind.	6.0	0.67
I could get to information quickly.	5.5	1.27
Information is organized well within the tabs and subtabs.	5.9	1.20
The user interface supports all functions needed for me to perform my job.	5.8	0.92

*scale: 1=strongly disagree, 7=strongly agree

Outcomes

Specific Aim #2: Test Specific EHR Interface Design Requirements

General EHR Prototype Development

The main outcome of the project is the EHR prototype, Tandem EHR. The name signifies the need for teamwork in primary care and with the patient. Features and benefits of the Tandem EHR prototype include:

a) Improving the quality of patient information and its display through data integration, decreasing data overload, and protection of sensitive information;
b) Supporting clinician assessments about the status of the patient, their medical condition(s), the plan of care, and diagnostic and therapeutic decision-making including what is new or changed, recency or currentness, missingness, critical or caution warnings, due or overdue, and sensitivity of data;
c) Tracking the status of actions, e.g., orders, tasks, patient test results, referrals and recommended care;
d) Facilitating with follow-up of patient problems;
e) Facilitating team coordination around patient related-tasks;
f) Supporting care outside of the visit setting;
g) Decreasing clinicians' data entry and data management demands.

The Tandem EHR is a patient-care-plan-based EHR. All patient-related information, data integration, data tracking, and facilitated teamwork revolves around an established patient care plan. The remainder of this section is a general description of the EHR prototype. The design content is derived directly from the GDTA results, i.e., the cognitive requirements. The EHR design is similar for all team members, so that all users share the same views of the EHR content and patient chart, helping to maintain SA across the team. The design allows for customization at the level of user type or user where appropriate.

The basic layout of the EHR prototype includes in the patient chart a patient header that remains static while the chart is "open." A chart viewing space has either full page or half page viewing areas for the specific pages in the EHR, allowing side-by-side reviewing of different content. Half pages can split into quarter pages to review data reports, graphs and lists of data. Content is available through a tab (section) and subtab (page) design. There are 5 major sections including Patient, Plans, Visit, Actions, and Status. Within each tab are 2-5 subtabs which correspond to pages in the patient chart interface. On the left side of the interface is the *Quick Pick*. This functionality provides an overview of the user's daily schedule and urgent tasks. The schedule shows the patient status, who they are with and whether they are ready to see someone on your team. A navigation bar at the bottom of the interface links to the user dashboard, clinic schedule, task manager, references, messages and search function.

We deliberately created a consistent look and feel throughout the prototype. The color scheme was carefully chosen based on maximizing all users' ability to discriminate colors. The basic color scheme uses shades of teal and gray and additional color use has meaning to help users with assessment of data, e.g., red is critical, yellow is caution, orange is overdue, pink is preferred, blue is new, etc. Icons and symbols were carefully created and user tested or selected from publicly available sources and are used throughout the design to share important information, e.g., action or patient status, and along with color, to display warnings. Both have hover functions that give more information about their meaning. 'Go to' icons and symbols allow one-click access to information on other pages.

Many new widgets and functionalities were developed to overcome situation awareness roadblocks in primary care. One particular challenge in primary care is understanding what information is new or changed about the patient since the last time the clinician interacted with the patient/patient information. A specific red/yellow/blue newly designed widget is located on the patient chart tab section and on each page of the patient chart with numbers indicating the amount of critical, caution or new information available overall and on each chart page. The widget also allows the user to navigate to those page areas to view the information.

<u>EHR Prototype Design Features: Patient Chart</u>

The following is a description of the patient chart sections (tabs and subtabs) in the prototype. The Patient tab has 5 subsections: Overview, Contact, Insurance, Social and History, of which two, the Overview and Social pages were built in the prototype. The Patient Overview page was designed to provide the user with an overview of everything important in the care of the patient and their care plan to rapidly gain situation awareness about the patient and build trust with them. It is a full-page design with a half page view of the patient social information and half page view of care plan "At a Glance" information, each with a dashboard level view information. On the patient page, current major life events, functional abilities (e.g., cognitive, physical and psychosocial abilities), life and lifestyle, health risks, social and economic issues, and health goals that impact care decisions are highlighted. On the At-a-Glance page care plan problems, vital signs, due and overdue care, medication use, and similar data are highlighted. Each page features the ability to immediately go to information sources for more information. On the Social page the user can enter or review key social information about the patient while understanding the data provenance and importance. The information entered here flows into the Overview page. The intended purpose of the Contact page is to enter and review contact and demographic information for patient and caregivers. Similarly, the Insurance page is designed to enter and review information on insurance coverage, while the History page is to enter and review family medical history, surgical history, and past medical history. The cognitive requirements of the Contact, Insurance and History pages and initial sketched designs are available; however, the content was not developed in the prototype or user tested.

The next section is the Plans section. Plans includes Care Plans, Meds, Education and Evaluations. The Care Plans page allows to user to enter, review and manage all active and past care plans. A care plan is an integrated way of seeing all the goals and actions for taking care of the patient issue. It includes a list of patient problems and the ability see an in depth review of that problem and its care plan including goals, current and past actions such as orders, and a timeline view of the problem data. Importantly, for each problem the care plan links throughout the pages in the patient chart, integrating all care plan data and sharing pieces of this data in relevant pages of the prototype. The Plans Meds page allows the user to view and manage all medications taken by the patient, medication related warnings and patient allergy and adverse reactions. The Plans Education is where the user can view and manage all education provided to the patient, and the patient's education preferences and education barriers. This page was developed to meet a specific need for access to education-related information which is currently difficult to find in the EHR. The Plans Evaluations page contains the results of evaluations administered to the patient, such as the depression testing or breast cancer risk calculators, and allows recording of new evaluations. Evaluations can be viewed over time or by the specific evaluation type or test from a dashboard view and with easy access to the actual evaluation performed and are linked to care plans. The Plans Team page is intended to support viewing and managing all clinicians and caregivers providing care to the patient, including the PCP, specialists, nurses, MAs and other care team members such as nutritionists, case manager, and behavioral health specialists. The cognitive requirements of this page are available however the content was not developed in the prototype or user tested.

The Visit tab is where the user works on current office visits, or other types of visits such as e-visits or phone calls. It has 4 subsections, SOAP, Update, Summary and Billing. In the Visit SOAP page the user can enter and review the problems to be discussed during the visit, which can be modified, and where the user can document the history, exam findings, assessments, plans and instructions for each problem. The Visit Update was designed to help the user rapidly come up to speed with information about the patient's current status. The user can enter and review data collected on the patient for use during this visit including vital signs, medication use, evaluation results, lab and imaging results, and recent care received. The Visit Summary allows for end-of-the-visit visualization of the clinical assessments made, actions taken for each problem including plans for follow-up care, and patient instructions. The Visit Billing page is reserved for the user to provide additional information needed for coding and billing for the visit. While much effort in health systems goes into coding and billing for revenue generation and much time is spent on this activity by clinicians, this section was not a focus in our prototype. The cognitive requirements needed for this page and initial design ideas are available for this page but additional work was not performed to program into the prototype. The research team feels strongly that information needed for completing these tasks should be compiled automatically by the EHR system based on EHR review and actions taken by the users within the system and presented to the clinician's designee for review and completion

The Actions tab has two subsections, Orders and Summary. On the Actions Orders page, users create new orders, including for all types of orders such as medications, labs, imaging, and durable medical equipment, consultations, and education. A search feature allows orders to be suggested for a given patient problem or diagnosis. A filter feature allows filtering by order type. When completing specific orders, action alerts are visible on the ordering page to guide ordering safety. These warnings include safety information about interactions between different orders, allergies and adverse reactions, kidney and liver function interactions, and pregnancy and breastfeeding interactions. Relevant information is presented to assist the user with understanding the severity of the alert and making changes to improve safety or monitor for future safety events related to the order. On the Actions Summary page, users can view a list of all orders created for this patient, current and past, along with any current action alerts. Displayed with the order is the completion status and due status so users can easily recognize and complete any unfinished order, track order status and reorder expiring orders.

The last tab is the Status tab, with 4 subsections, Timeline, Tracking, List and Data. These were carefully designed to overcome SA problems with having a comprehensive view of the patient's health over time and to assist with tracking and monitoring the patient's planned and future care. The Status Timeline page allows the user a comprehensive view of all patient-related information over different timespans. Users can see changes over time (i.e., by day, week, month, year or decade) in patient's major life events, health conditions, vital signs, lab and imaging results, medications, and similar data. The information can be sorted or filtered in multiple different views to facilitate detailed or general overviews, e.g., by care plan problem or data category. Users can easily go to detailed information reports or view graphs to dive deeper into data elements. To assist with care planning, the timeline also displays future care, i.e., ordered/planned care to be delivered in the future. The Status Tracking page allows the user to track patient status on all active actions, including items ordered by the user or another team member, as well as medication use, recent care, open tasks, and overdue care plan items. The Status List page provides another way of easily accessing all patient information by data category, e.g., lab and imaging result reports or hospital and clinician visit reports. The Status Data page is where all patient-related information is stored. If a report is opened on another page, it will show up here. Users can make notes, highlight or mark on the reports for future use by themselves, their team or others.

In addition, prototyping was completed for a task manager system that is integrated throughout the prototype design to alert users to urgent tasks requiring attention and patient-specific tasks status while completing work in patient charts. The task manager system is divided into a general task completion, e.g., phone calls, chart documentation, medication refills, and a patient report manager, e.g., lab and imaging result reports. It assists with prioritization of task work completion and completion across the primary care team members.

EHR Prototype Documentation

We documented of all aspects of our prototype in two specification documents. The first describes the "widgets" or elements of design used across all the pages, such as icons and selection tools. The second describes the content of each page, how the functionalities work, and the goals, decisions and information needs met by the page and its specific features and functionalities. These documents are critically important for future translation of this prototype into a usable EHR for use in primary care.

Discussion & Conclusions

Electronic health records (EHRs) were intended to improve care delivery by increasing access to patient information and thereby quality of care. However, their potential has not been fully realized. Notably, they have failed to support the cognitive work of clinicians and teams in primary care, for example, decision-making, communication and collaboration. Tandem EHR was specifically designed to overcome current EHR inadequacies. We successfully used GDTA, a cognitive task analysis method used in industries where complex work is performed, and situation awareness-based design principles to study the cognitive work of primary care physicians, APPs and their teams, and design a primary care based EHR prototype, Tandem EHR. Positive results from extensive end-user testing suggests this prototype's design features could improve cognitive work, teamwork and decision making in primary care that can translate into improved quality of care and worker satisfaction.

Significance & Implications

It is our belief and a testable hypothesis that translating the Tandem EHR prototype into a usable primary care EHR will 1) improve productivity, 2) increase access to needed information and decision-making, 3) improve practice satisfaction and decrease burnout levels, 4) improve the quality and safety of the care delivered to primary care patients, and 5) ultimately decrease costs for organizations through less waste and staff turnover. We have valuable products to disseminate and implement from this work including the cognitive requirements of PCPs and their teams and the EHR interfaces themselves. We are strongly motivated to disseminate our products and see them used in practice.

6. List of Publications and Products

Products (copyrighted):

1. Tandem EHR Prototype
2. Goal Directed Task Analysis Maps: Nurse & Medical Assistant Roles, Physician & Advance Practice Professional Roles

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Electronic Resources from Study

The study website: tandemehr.medicine.wisc.edu has available multiple tools that interested parties can use to assist with completing a goal directed task analysis or performing end user testing. These include (1) the Core Team Member Interview Guide and (2) the Pre-Visit Interview Guide.

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