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UNDERSTANDING NURSE CREATED COGNITIVE ARTIFACTS: PERSONALLY-CREATED-COGNITIVE-ARTIFACTS AS EXTERNAL REPRESENTATIONS OF DISTRIBUTED COGNITION

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Dissertation

Understanding Nurse Created Cognitive Artifacts:
Personally-Created-Cognitive-Artifacts
as External Representations of
Distributed Cognition

By

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Dedication

To my daughter and son-in-law,
Michelle and Steve,
a wonderful couple and loving parents of
my beautiful granddaughters,
Sabrina and Tessa,
born during this project and the light of my life.

To my fellow classmates, whose support, advice, and guidance
have been instrumental to achieving this goal;
I am very grateful for your help.

To the nurses
who participated in my research
and expressed enthusiasm,
support, and excitement for this research project.

To two individuals who created several break through insights,
and supported and encouraged me
through and over the truly rough moments of this journey:
Dr. James P. Turley
Dr. Adol Esquivel

Thank you all for your faith, patience, and perseverance.

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INTRODUCTION

Knowledge workers assimilate complex arrays of data to support the cognitive work of their profession. Registered nurses (RN) are knowledge workers who are dependent upon a complex array of clinical information to inform patient care decisions. The RN is continually evaluating the clinical signs and symptoms of the patient in the context of diagnostic and therapeutic interventions, and this data needs to be immediately accessible to support the nurse's cognitive processes. The practice environment of the nurse is dynamic, interruption-driven, incorporating multiple priorities, and the requisite data is distributed among various repositories and artifacts in that are placed in a variety of locations. A comprehensive summary of each patient's clinical data is not available to the nurse assigned to care for that patient. To bridge the gap between reality and clinical need, nurses prepare a clinical summary, or cognitive artifact, each of the patients in their care on a daily basis. This cognitive artifact is prepared for use by the nurse caring for the patient and contains demographic, assessment, symptom, therapeutic intervention, medication, and related data to aid the nurse in care delivery. This **p**ersonally **c**reated **c**ognitive **art**ifact has been named the PCCAT.

Although the PCCAT is important to the nurse, it is not without risks to patient safety. The data recorded on the PCCAT is transcribed from other sources and is at risk for transcription error. Data may also be inadvertently omitted, duplicated, or recorded on the wrong patient. The data recorded early in the day becomes less current as new data is made available in the source system. The nurse may be delayed in accessing source systems, possibly delaying therapeutic interventions or making care decisions with outdated information.

The above information prompted this study to determine the criteria and requirements necessary to create an information technology solution to the PCCAT, offering the nurse the benefits of the PCCAT while minimizing or eliminating the risks. A technology solution could also save the nurse time spent each day to prepare the PCCAT. Prior to embarking on the

development of a technology solution, a deeper understanding of the relationship between the nurse and the PCCAT was necessary. The data the nurse recorded and added to the PCCAT needed to be identified and defined. We also needed to understand the heuristics the nurse used to select the data that was recorded. While we believed that the PCCAT supported the cognitive work of the nurse, such as working memory and other cognitive activity, the context and nature of the cognitive support needed to be identified and explored.

Portions of the program of research are described in the three manuscripts presented as a PhD dissertation about the study of the knowledge representations and structures embodied by the PCCAT. The research was a multi-method, qualitative, triangulated study conducted on three inpatient units at a comprehensive cancer center located in southern United States. Site selection was convenience, and the participating units were a nonrandom convenience selection. Clinical nurses who worked on the study units and who spent a minimum of 50% of their worked time in direct patient care were eligible to participate.

The research program began with a review of the literature to understand what has been learned about personal cognitive artifacts. We found that studies of personal cognitive artifacts such as the PCCAT have not been reported. Some work has been reported related to the shift report nurses share when the departing nurse provides a clinical update to the arriving nurse. These reports do not report if or how the information exchanged, or any written documentation shared during the report, influenced the nurse after the report was completed. Research related to other cognitive artifacts has been reported. A study of cognitive artifacts in an operating room (OR) setting enabled researchers to understand the role of artifacts in supporting the technical, organizational, and workflow demands of the OR, and assisted in the recognition of gaps in an already existing information system. Researchers concluded that in-depth study of cognitive artifacts in the OR is a prerequisite to understanding this technical setting, the problems the artifact is intended to address, the hazards and risks present in the environment, the ways in which cognitive artifacts support distributed cognition, and the dimensions and complexity of the

elements of distributed cognition in the OR environment (Nemeth, Cook, O'Connor, & Klock, 2004).

This research was based upon the assumption that the PCCAT is an instance of a cognitive artifact. An early step in the program was to establish that the PCCAT is a cognitive artifact through a concept analysis using the process established by Walker and Avant (Walker & Avant, 2005), and is the subject of the first manuscript, "Conceptual Analysis: Externalizing Nursing Knowledge". We discovered that a concept analysis of cognitive artifacts had not been published, so we amended the plan and converted our concept analysis into a dual process. The purpose of the concept analysis was to clearly define the attributes and limitations of cognitive artifacts, and their antecedents, consequences, and external referents. Once the characteristics of the concept entitled 'cognitive artifact' had been established, the same concept analysis process was employed with the PCCAT. Finally, the attributes, limitations, antecedents, consequences, and external referents of the PCCAT were compared to those of the cognitive artifact. The process firmly established the PCCAT as an example of cognitive artifacts. This process placed PCCATs in the concept class of cognitive artifacts and allowing us to determine if other concepts are the same as the cognitive artifact, or only similar to but differing in a least one significant way.

The concept analysis, establishing PCCATs as an instance of a cognitive artifact, enables assignment of the seven attributes of a cognitive artifact to the PCCAT, as established by Zhang and Patel (2006). The seven attributes are 1) reduction of user memory, 2) guiding recognition and understanding inferences to support rapid data assimilation, 3) augmenting user knowledge and internal representations,4) supporting user perceptions and cognition without requiring conscious effort of the user, 5) promoting more efficient and effective user action, 6) minimizing abstraction and support effective decision making, and 7) channeling decision making by maximizing accuracy and minimizing user effort. We also established that the PCCAT has an additional attribute not shared with cognitive artifacts, namely that the clinical

data record and display of the PCCAT is prepared for the personal use of a single clinician.

The second manuscript is a methods paper entitled "Research Methods: Exploring Cognitive Work". The manuscript describes the multi-method, qualitative, triangulated methodology employed to study a knowledge representation and knowledge structure used by clinical practitioners. The knowledge representation (PCCAT) was analyzed for domain content, categorized, and coded, using document review as the method. We studied the interaction between external knowledge representations and internal knowledge representation using shadowing techniques. Internal knowledge representation was further explored through the use of interviews and a clinical scenario. Data analysis was concurrent ad iterative. Each phase of data collection informed understanding and insight of past phases, and informed and guided subsequent phases.

The multi-method design allowed us to experience and explore issues that may have been missed in a study with a less complex design. Shadowing disclosed the scope of distributed cognition in the clinical environment and added important context to the domain content identified during document analysis. Shadowing also revealed the how and when the subjects accessed external knowledge representations and transcribed information to the PCCAT, information that could not be identified during document review and may not have surfaced during subject interviews. Subject interviews created a window to the meaning and value of the PCCAT for the nurse, and enabled the nurse to share personal perceptions. Collectively, the multi-method design allowed us to peal the layers of meaning and use surrounding the document known as the PCCAT.

The third manuscript, "Making the Cognitive Work of Registered Nurses Visible" describes data analysis, insights, and conclusions. The analysis of the multi-method design enabled us to 1) prepare a taxonomy of the PCCAT knowledge representation and knowledge structure, 2) develop insight regarding the scope of distributed cognition present in the clinical environment and the barriers it presents to comprehensive summaries of patient condition, 3)

establish how the knowledge representation supports working memory and how the nurse designs it to serve this purpose, 4) discover the importance of personally handwriting data to the recall of the nurse, 5) identify the importance of information visualization to organization and prioritization, 6) describe the information sources the nurse accesses to prepare the PCCAT, 7) describe how the nurse uses the PCCAT to support reflection and cognition, 8) discover the use and importance of visual cues, and 9) establish the PCCAT as a temporary data repository for later documentation or communications. Our work revealed the passion nurses have for their PCCAT, and the anxiety associated with loss of this knowledge representation. We also discovered that, while formats are often similar, there is also significant disparity in how nurses wish to see the data displayed on their PCCAT. Finally, this work indicates that creating an information technology alternative to the current PCCAT is more complex than originally envisioned. It is suggested that until the technology has sufficiently matured to support much greater flexibility that permits personal customization and manipulation of data, creating an electronic version should be deferred.

These three manuscripts connect the stages of the research journey to discover the purposes of a knowledge representation and structure, the PCCAT that is created and used by registered nurses each day. The attributes of the PCCAT knowledge representation and knowledge structure have been defined; a taxonomy and ontology have been established; a comprehensive methodology for study of knowledge representations and knowledge structures has been created; and the role of the PCCAT in the cognitive work of the clinical nurse has been identified. This work should assist systems analysts, informaticians, and developers who desire to create patient clinical summaries, now and in the future.

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Manuscripts

Conceptual Analysis: Externalizing Nursing Knowledge

CONCEPT ANALYSIS: EXTERNALIZING NURSING KNOWLEDGE

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ABSTRACT

We use concept analysis to establish that the report tool nurses prepare, carry, reference, amend, and use as a temporary data repository are examples of cognitive artifacts. This tool, integrally woven throughout the work and practice of nurses, is important to cognition and clinical decision-making. Establishing the tool as a cognitive artifact will support new dimensions of study. Such studies can characterize how this report tool supports cognition, internal representation of knowledge and skills, and external representation of knowledge of the nurse.

INTRODUCTION

Availability of accurate clinical information at the point of care is crucial to nursing practice. Nurses meet this need by preparing a summary of patient information on their assigned patients at the beginning of a shift. Often referred to by folk names such as "cheat sheet", "brain", or "handover", we will characterize these clinical summaries by the acronym PCCAT, or **p**ersonally **c**reated **c**ognitive **art**ifact. A definition of the PCCAT is that of a document that the nurse prepares for the purposes of creating a comprehensive summary of clinical data about the patient, a source for data recall, and a tool to support clinical decision-making.

Cognitive artifacts are external data displays that augment and influence human reasoning, understanding, and decision-making (Patel, Kushniruk, Yang, & Yale, 2000). Cognitive artifacts are embedded in our daily life, and include shopping lists, newspapers, roadmaps, and global positioning systems (GPS). The purpose of this paper is to establish the PCCAT as an example of the cognitive artifact concept and thus introduce a new understanding of this important tool, thereby supporting future assignment of the attributes of cognitive artifacts to this type of document. The attributes of the PCCAT and cognitive artifacts will be identified and characterized through application of the concept analysis process described by Walker and Avant (Walker & Avant, 2005b). The review will conclude with a discussion and implication of

the findings. This paper is part of a larger project designed to define the requirements for a 'next generation' electronic PCCAT.

HISTORY OF THE PCCAT

Nurses are responsible for contributing to and coordinating the multidisciplinary plan of patient care. This responsibility demands access to accurate, comprehensive clinical data that will support a patient-centered care plan. Data recorded on the PCCAT are gathered from the patient and family, colleagues, the chart, the electronic medication record (EMR), and other clinical information systems (CISs), as well as observations added by the nurse. Assuring availability of the most up-to-date clinical data can be challenging, requiring the nurse to access source systems throughout the shift.

Studies of PCCAT-like documents have not been reported in the healthcare literature. Published research of nurse-generated cognitive artifacts has been limited to documents that support shift-to-shift report between the nurses of the off-going and on-coming shift (Myny, Verdonck, Danneels, Verwaeren, & Decruyenaere, 2005; Strople & Ottani, 2006). One study has been reported of a cognitive artifact used by a multidisciplinary operating room team after implementation of an information system. These researchers found that without an intimate understanding of workflow, knowledge sharing, handoffs, and shared work activities, information systems may actually impede work, resulting in workarounds and added process steps to accommodate system deficiencies. Ineffective design may also increase the risk of error despite the intention to support technical, organizational, and workflow demands (Nemeth, O'Connor, Klock, & Cook, 2006).

The original PCCAT involved gathering and recording data using simple paper and pen, and this mode of preparation continues to be widely used today. However, in today's technology-rich environment, the manner in which PCCATs may be developed is evolving. In environments with an EMR, practitioners may generate a clinical summary for each patient. Practitioners may also create PCCAT documents by transcription of pertinent clinical data into

word processor or spreadsheet applications, thus preparing a summary for the oncoming shift. The PCCAT is customized by the addition of data the individual practitioner considers important. Evaluating the PCCAT in the context of how it is used by healthcare practitioners to support cognition, memory, and decision-making will highlight its strengths and limitations as an effective cognitive artifact.

While the PCCAT has several highly desirable features, it also has serious drawbacks that may compromise patient safety. Risks represented by the PCCAT include transcription errors, missing or failing to record data that are key to clinical decision processes, recording data on the incorrect patient, and degradation of data currency unless regularly updated during the shift (noted during observations of clinical practice) (Institute of Medicine, 2004).

METHODS

Analysis of the PCCAT and of cognitive artifacts was achieved using the concept analysis model developed by Walker and Avant(Walker & Avant, 2005a). This process involves examining the attributes of a concept in order to identify how that concept is similar and/or dissimilar to other concepts. This analytical process has 8 steps:

1. Selecting a concept

2. Determining the aims or purposes of the analysis

3. Identifying all uses of the concept

4. Determining the defining attributes

5. Identifying a model case

6. Identifying borderline, related, contrary, invented, and illegitimate cases (invented and illegitimate cases are optional and may be included when their addition provides clarification of the concept)

   a) Identifying the defining attributes of a concept can be confusing, and the process may be made easier by identifying the attributes of a concept that seems similar to the concept you are studying. The process of examining the attributes of what

appear to be the same or similar concepts can assist the researcher in

determining the classic attributes of the concept.

7. Identifying antecedents (which must occur before the concept exists and cannot be a defining attribute) and consequences (which must occur in response to, or as a result of, the occurrence of the concept)

8. Defining empirical referents or specific examples (which support content and construct validity and are frequently equivalent to the defining attributes) which demonstrate an occurrence of the concept

The goal of this concept analysis is to establish that the PCCAT is an instantiation of a cognitive artifact, laying the foundation for further study of the PCCAT.

CONCEPT ANALYSIS OF COGNITIVE ARTIFACTS

Identify uses of the cognitive artifact concept

"Cognitive artifact" was coined by Norman (1991) to describe information display objects as "artificial devices designed to maintain, display, or operate upon information in order to serve a representational function and that affect human performance" (Norman, 1991). Generally, cognitive artifacts are physical objects designed for a specific purpose and that facilitate thinking, evaluation, and consequent responses or actions (Norman, 1992). Bang and Timpka (2003) characterized cognitive artifacts as tangible objects intentionally created to aid, enhance, or improve thinking and reasoning (Bang & Timpka, 2003). According to Nemeth et al., cognitive artifacts have various physical forms --- such as paper, whiteboards, and schedules --- that support visualization of temporal data, provide insight into the nature of the work practitioners, and illuminate important interactions and relationships in the clinical setting (Nemeth, Cook, O'Connor, & Klock, 2004; Nemeth, Nunnally, O'Connor, & Cook, 2006; Nemeth, O'Connor, et al., 2006; Nemeth, O'Connor, Klock, & Cook, 2007).

The characteristics of cognitive artifacts extend beyond data presentation. Cognitive artifacts influence the interaction between an individual and a task, both the nature of the task

and how the individual understands it. Task performance is supported and facilitated by the application and use of the data represented by the artifact, with the knowledge, skills, and experience of the individual (Norman, 1992). An individual's understanding of the configuration, content, data relationships, and data of a cognitive artifact influences how new information is shaped, organized, evaluated, and integrated (Patel, et al., 2000). Once one is aware of cognitive artifacts in the environment, many examples can be identified. Examples of cognitive artifacts commonly found in the healthcare environment are shown in Table 1.

Table 1: Examples of Cognitive Artifacts Prevalent in Healthcare Environments

▪ Assignment boards or sheets	▪ OR schedules
▪ Chalk boards	▪ Clinic appointment schedules
▪ Work lists or other reminders of clinical tasks to be completed	▪ Spreadsheets
	▪ Medication dose calculators
▪ Medication administration records	▪ Flowsheets
▪ Electronic medication records	▪ Electronic or hand written handwritten [make it one word] bed-boards
▪ Medical records/charts	
▪ Fall precaution signage	▪ Physiologic monitors
▪ Barriers to freshly mopped floors	▪ Automated vital sign equipment
▪ Clinical pathways or guidelines	▪ Intravenous infusion pumps
▪ Employee identification badges	▪ "Do not awaken for vital signs" sign on door
	▪ Way-finding and other directional signage

Defining attributes of cognitive artifacts

Cognitive artifacts aid understanding and augment our abilities. We use cognitive artifacts to interpret our environment and help us create meaning. This enables us to evaluate and accept or reject new data, adapting our current knowledge as appropriate. Effective cognitive artifacts have specific properties, originally described by Zhang, and refined by Zhang

and Patel (Zhang, 1997; Zhang & Patel, 2006), and listed in Table 2. These properties illustrate that cognitive artifacts are more than memory aids or data repositories --- they also aid critical thinking and decision making while reducing distractions resulting from abstraction and the recall effort.

Table 2: Attributes of Cognitive Artifacts (Zhang & Patel, 2006)

- Reduce memory load of the user,
- Guide recognition and understanding of inferences, supporting rapid assimilation of data,
- Augment user knowledge and internal representations,
- Support user perceptions and cognition without requiring conscious effort of the user,
- Promote more efficient and effective user action,
- Minimize abstraction and support effective decision making, and
- Channel decision making by maximizing accuracy and minimizing user effort.

Cognitive artifacts in healthcare have the following additional attribute:

- Clinical data record and display prepared for the personal use of the clinician.

A model case of a cognitive artifact

Figure 1 is a model case of a cognitive artifact, depicting a graphic representation of the temporal relationship of furosemide administration (a potassium-wasting diuretic) and a patient's serum potassium (K^+) levels. The graph shows administration of furosemide followed by an incremental decline in the patient's serum potassium level, and a subsequent increase in the potassium level after potassium infusion and furosemide dose reduction. The addition of serum digoxin levels and indications of the patient's cardiac rhythm, as well as symptoms reported by the patient, would provide additional clinical insight. The relationship between the practitioner's knowledge, experience, and skill and an information display supports data assimilation and facilitates clinical decision-making. In this model case a practitioner could quickly recognize

potential patient complications, anticipate more serious complications, and intervene appropriately.
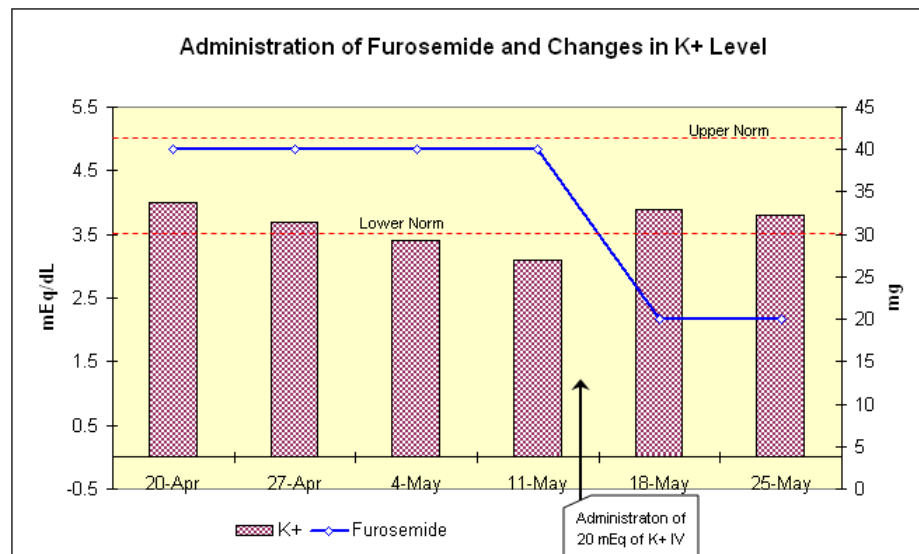
Figure 1: Example of a model case of a cognitive artifact

Related, borderline, contrary, and invented cases of a cognitive artifact

A related case to the cognitive artifact is the data record maintained during cardiac resuscitation. Typically, these data include procedural interventions such as cardiac compression, drug administration, and defibrillation, as well as the patient's response to such interventions as evidenced by cardiac rhythm, vital signs, pupil reactivity, and arterial blood gases. Real-time documentation of these interventions and the patient's response 1) eliminates the need for the practitioner to recall the specific and complex sequence of events; 2) promotes efficient user action by enabling specific and immediate feedback to the resuscitation team; 3) guides recognition and inferences when the data are transcribed to the permanent record; 4) channels effective decisions as, for example, the clinician progressively increases or decreases medication dosages or cardio-version; 5) minimizes abstraction through provision of specific data regarding medication dose, administration time, and patient response; and 6) limits abstraction through real-time documentation of events. The event log maintained during a cardiac resuscitation shares many, but not all, of the attributes of a cognitive artifact. It is not

created for personal use, and the content may or may not meet the content and data display needs of the individual practitioner. Further, the level of abstraction may vary significantly based upon the use of abbreviations, acronyms, and personal reminder notes. The cardiac resuscitation record is read and used by multiple practitioners, and consequently is designed to meet the general documentation and cognitive needs of several individuals.

Recording a patient's vital signs on a paper towel, piece of scratch paper, the uniform, or even on the hand is an example of a borderline case of a cognitive artifact. This practice may occur when the practitioner is rushed, had not intended to take the patient's vital signs at that particular time, or forgets to bring a computer or chart form to record the data. Recording the vital signs on any available surface 1) reduces memory load, particularly if the practitioner is delayed in transcribing the data; 2) incorporates specific data, eliminating abstraction; 3) promotes efficient action by the practitioner, reducing the need to retake vital signs if the data are forgotten; 4) maximizes accuracy of the medical record and the data recorded; 5) supports the practitioner's knowledge of the patient's clinical condition; and 6) is intended only for temporary and/or personal use. However, the data recorded on the paper towel or scratch paper are not formatted nor in a context that helps develop inferences or perceptions about the patient, and thus do not share the attributes of a cognitive artifact.

An invented case of a cognitive artifact outside the domain of healthcare practitioners is the trip log maintained by long-distance truck drivers. In an effort to assure truckers do not exceed the legal maximum of 70 worked hours in an 8-day period, the Department of Transportation requires truckers to maintain driving logs. However, most drivers maintain a much more detailed set of data that provides a comprehensive summary of driving activity, including hours worked and driven for the past 7-day period, fuel expense, miles driven per state, meals, lodging, toll expenses, loaded and empty miles driven, and other valuable data. These data provide information to guide decisions regarding availability for hire, trips and/or routes that increase profits, personal expenses, and so forth. Trucker logs have become

increasingly sophisticated, and many truckers now use specially designed software packages that maintain serial summaries to support timely decisions.

Antecedents and consequences of cognitive artifacts

Antecedents to a cognitive artifact in the clinical setting would be a direct or indirect care relationship with a patient. The care provider has an understanding and knowledge of the patient's clinical condition that creates a need to have specific clinical information readily available. The amount and complexity of clinical data the care provider needs cannot be reasonably stored in short-term memory and recalled accurately.

Consequences of a cognitive artifact in the clinical environment would be the availability of data defined by the practitioner as necessary to support his or her care of the patient. The clinician has the data he or she needs when consulting with colleagues. Data are formatted to convey meaning to the practitioner and to support clinical decision-making. Figure 2 depicts the antecedent and consequence elements of a personal cognitive artifact.
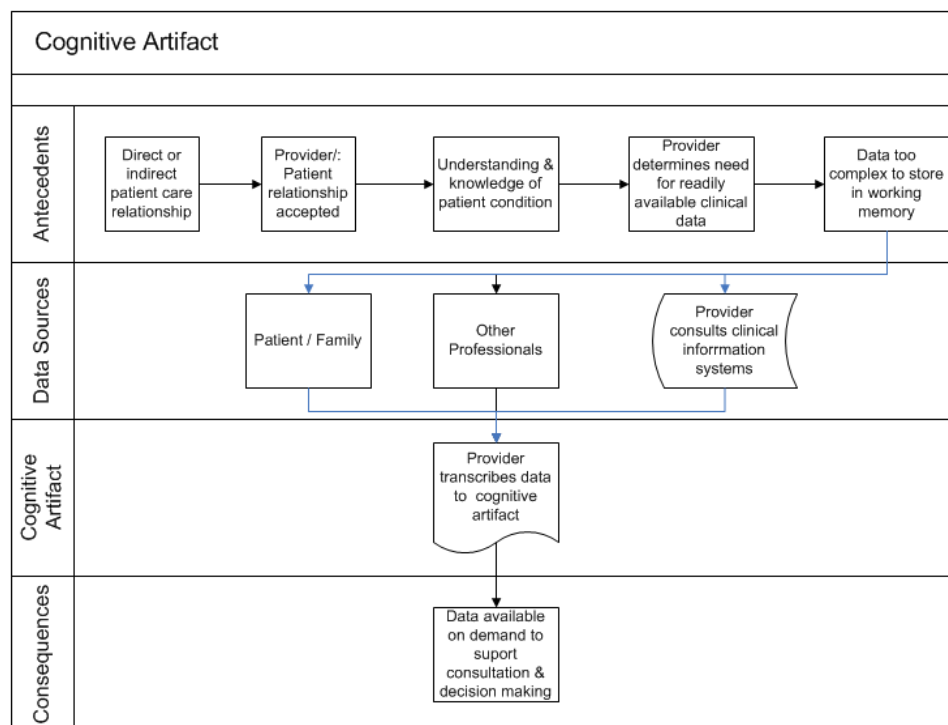
Figure 2: Cognitive Artifact Concept Antecedents and Consequences

Empirical referents of cognitive artifacts

Empirical referents are indications of the existence of a cognitive artifact. Phenomena that enable identification of a cognitive artifact can be indirectly derived from the attributes established by Zhang and Patel (Zhang & Patel, 2006). A personally created cognitive artifact demonstrates an understanding of the data needed to support working memory and personal knowledge. The process of creating a cognitive artifact demonstrates that the individual creating it is aware of the knowledge they believe is necessary to augment their personal knowledge, and serves as an indirect representation of that knowledge. The practitioner controls the degree of abstraction and the ways in which data can contribute to his or her efficiency.

CONCEPT ANALYSIS OF THE PCCAT

Identify uses of the PCCAT concept

The utility of the PCCAT begins as the nurse creates it; the very process of gathering and recording the data both initiates and is the outcome of reflection and care planning (Bates, 2005; Norman, 1993; Powell, 1989; Schon, 1983). As the nurse plans for the needs of the patient, he or she prioritizes and plans task sequencing, records data required to support specific tasks or decisions, and considers equipment needs. The very process of creating or customizing the actual PCCAT encourages and stimulates thoughtfulness.

The PCCAT is frequently consulted during discussions with other healthcare professionals. Data recorded on the PCCAT may be used to assure the purpose of the interaction is achieved, prioritize the information to be discussed, and/or ensure that the necessary information is available. The nurse may also consult the PCCAT during a discussion to refresh, recall, or record information related to the conversation (noted during observations of clinical practice).

As the nurse evaluates data, the PCCAT encourages reflective analysis, and may prompt judgments and decisions about the plan of care and the actions that need to be taken. These judgments may promote discussion with colleagues regarding changes in the patient's clinical condition, and/or guide plan-of-care decisions. The PCCAT eliminates the need to memorize the data, enabling the nurse to focus on assessing the data and critical thinking.

The PCCAT provides a frame of reference for the nurse when prioritizing work and determining the care delivery tasks to be delegated to unlicensed care providers (UCP). Once tasks are delegated, the PCCAT serves as a reminder to follow up with the UCP regarding the outcomes of delegated tasks.

The PCCAT is believed to support working memory --- the temporary, limited storage of data that supports cognition and long-term information storage (Baddeley, 2000; McNamara & Scott, 2001). Research indicates that working memory has the capacity to concurrently maintain about seven pieces of information, plus or minus two (Baddeley, 2000; Miller, 1994; Tuholski, Engle, & Baylis, 2001). The relationship between working memory and cognitive artifacts suggests that nurses developed and expanded the content of the PCCAT to support memory limitations and the need for immediate access to information about the patient, the plan of care, and care delivery tasks. Without the support of external representations such as the PCCAT, the nurse would be at significant risk for errors of omission or commission.

Nurses are interrupted multiple times during a shift, often while evaluating clinical data, formulating care plans, or providing patient care. Interruption, an unplanned intrusion that redirects attention and interferes with or stops task performance (Brixey, et al., 2007; Coiera, Jayasuriya, Hardy, Bannan, & Thorpe, 2002; Institute of Medicine, 2004), is an accepted facet of the clinical environment. Interruption --- such as changes in the patient's clinical status, changing priorities, communication with other practitioners, reporting results of a delegated task by the UCP, and clinical alerts from biomedical equipment or clinical information systems --- can distract the nurse and serve as a precursor of error by displacing data or care tasks from

the nurse' working memory. The PCCAT may provide support by assisting the nurse to redirect his or her attention to the location and focus in the moments prior to the interruption.

The PCCAT also serves as a temporary data repository. Whether using a decentralized point-of-care documentation system, a centralized documentation system, or a hybrid, the nurse can write reminders and key clinical data on the PCCAT with the intention of transcribing the information to the patient record at a later time.

Defining attributes of the PCCAT

The PCCAT, usually comprised of one or a few pieces of paper, is lightweight and highly portable, accommodating the data needed by a busy clinician. PCCAT storage requires only the pocket of a lab coat, a jacket, or a folio. Creating a PCCAT is generally low-tech, often as simple as writing data on a piece of paper with a pen or pencil. The physical nature of the PCCAT supports a highly flexible format that accommodates the nurse's changing information needs and the changing clinical condition of the patient. The PCCAT is resilient, easily reformatted, and durable for short-term use. They do not require electricity and can be quickly discarded in secure disposal systems designed to accommodate the Health Insurance Portability and Accountability Act (HIPAA) regulations (Office of Civil Rights, 2003). These physical and functional characteristics of the PCCAT are summarized in Table 3.

Table 3: PCCAT Attributes and Limitations

Attributes of the PCCAT	Limitations of the PCCAT

▪ Physical characteristics:
  o Portable
  o Lightweight
  o Requires minimal storage
  o Usually created with low-tech paper and pen
  o Flexible
  o Resilient
	▪ Limited or absent graphic data presentation
	▪ Limited indication of data relationships
	▪ Degradation of data currency
	▪ Absence of dynamic properties
	▪ Time required to prepare each shift
	▪ Lack of an alert when new data available
	▪ Time required to access new data

o Requires no external power to operate	▪ Potential for transposition errors
o Easily discarded	▪ Possibility of unintended disclosure (due to loss of the PCCAT) of protected health information (PHI)
▪ Summary of requisite clinical data	▪ Potential for violation of HIPAA rules
▪ Resource during consultation	
▪ Supports prioritization	
▪ Temporary data repository	
▪ Supports working memory	
▪ Supports decision making	

(*Preliminary based upon discussions with and observation of practicing clinical nurses; this list of attributes and limitations will be tested in future research)

Model case of the PCCAT

A clinical nurse's experience of caring for a patient with acute myelogenous leukemia (AML) provides a model case of the PCCAT. The PCCAT template the nurse used was a combination of information gathered by the nurses caring for the patient during the previous shift (Figure 3) and personally gathered data (Figure 4). The following vignette illustrates the model case.

When she arrived on the hematology unit, Estrella, a clinical nurse, learned she was assigned to care for Sabrina, a 45-year-old female with AML. Because caring for hematology patients requires a complex array of clinical data, Estrella used two documents as clinical data references during her work shift. One document was the summary report sheet (SRS), which contained a clinical summary prepared by Jonathon (Figure 3), the clinical nurse who cared for Sabrina prior to Estrella's arrival. Jonathon's summary of Sabrina's condition included pertinent data from various CISs.

Room	Name MRN DX BMT MD	Admit reason, Chemo, Hx	Allergies	Isolation	Code Status	Fall	Labs	I&O Wt	Cont Infusions /PCA	PRN / Blood	Assessment	Scheduled tests that need follow-up; Discharge date & needs
5555	Doe, John 123456 30yo Adm 11/01/07 AML MUD 11/07/07 D+16 Dr. Smiley	Busulfan /ATG Hx HTN	Penicillin / Zosyn		Full	Yellow	WBC: 2.3 Hbg: 8.4 Plts: 21 Na: 142 K: 3.9 Phos: Cr: 0.6 BUN: 6 Tbili: 0.9 Mg: 1.5 Fk:	I&O: -250 Wt: Adm: 129.3 11/19: 121.1 11/20: 122.5 11/21: 122.9 VRE: needed	LTL CVC Teg 11/17 IVF@42 Mani:11/20 FK@10 NS@11 PCA: Dilaudid D:1mg q30	Simethecon x1 for indigestion 1 unit platelets 11/22 @1900	Mucositis / esophagitis Grade 3; uses Yankaur t0 suction oral secretions	Accu-Cheks 06/11/16/22 w/ sliding scale – Humalog/Lantus Accu-Chek @ 2100 = 154 Keep platelets >30

Figure 3: Sample Portion of Estrella's SRS as prepared by Jonathon

After printing the SRS, Estrella prepared a personal report form (PRF), adding clinical data she wanted to have immediately available which was not recorded on the SRS, such as the patient's ordered intravenous fluids, subcutaneous and oral medications, dose, route, and scheduled administration time. Estrella used color coding unique to her personal needs on both the PRF and the SRS (Figure 3 and 4). Both the SRS and the PRF were carried in Estrella's pocket throughout the shift.

Figure 4: Sample Portion of Estrella's PRF

Estrella referred to the SRS and the PRF when she delegated care delivery tasks to the UCP and again when the UCP reported task results. Estrella also consulted the PRF and SRS as she briefly summarized the progress of her patients for the charge nurse. Later in the afternoon, she referenced the PRF and SRS while consulting with the case manager. Physician rounds prompted Estrella to refer to the PRF and SRS as she shared recent vital signs, pain patterns, appetite, and activity tolerance. In addition to the above, Estrella also telephoned the attending physician to discuss recently received recent lab results in the context of the current plan of care.

The SRS and PRF served as Estrella's data logs throughout the shift. She accessed the laboratory information systems twice before new lab values were available, recorded the values on the PRF, and later transcribed the data to the electronic SRS in preparation for shift handoff. Estrella also recorded vital signs taken throughout the shift, indicated the time medications were administered, and made notes regarding assessment data (following a discussion with the patient and her husband). In each of these instances, the data were later entered into the patient's medical record.

Near the end of her shift, Estrella began to prepare the electronic SRS for the next shift. She updated the data Jonathon had recorded that morning, deleted information no longer relevant and added new data she had collected during the shift. Estrella referenced data on her PRF as she updated the assessment data recorded on the SRS. She consulted both the SRS and the PRF during shift report and as she documented in the clinical record.

The model case demonstrates each of the defining attributes of the PCCAT.

1. The PRF and SRS are low-tech, highly portable, lightweight, durable, flexible, easily discarded, and require minimal storage space and no external power.

2. The data Estrella recorded on the SRS and PRF represent a summary of the clinical

data she believed was necessary in order to give appropriate care to her patient.

3. Estrella referenced the SRS and the PRF throughout the day in a variety of
    situations and also used them to help prioritize activities.

4. The SRS and PRF served as temporary data repositories as Estrella recorded
    data for later use.

5. Estrella referenced the SRS and PRF throughout the shift when making
    decisions and to assist recall of important data.

In this example, the SRS and the PRF shared the attributes of a PCCAT. Estrella's need for clinical data about the patient was met. The risks represented by the PCCAT were present but accepted by the healthcare personnel due to the absence of alternatives.

Related, borderline, contrary, and invented PCCAT cases

Related cases are connected to the study concept, but do not share certain attributes (Walker & Avant, 2005b). It is this approximate, "close but not quite there" quality that helps to define the study concept and demonstrate its connection with the related case. For example, dry-erase boards afford practitioners with access to a limited snapshot of clinical information, such as a patient identifier, the nurse assigned to care for the patient, the patient's attending physician, room number, and, possibly, information related to clinical service, as well as scheduled diagnostic or therapeutic interventions. While dry-erase boards are not lightweight or portable, they demonstrate many of the other physical attributes of PCCATs: low technology, durability, flexibility, no requirement for external power, and readily available data. The content of the dry-erase board is limited to the consensus of physicians, nurses, case managers, and so forth, who use the board and determine the data to be included. Because of this, dry-erase boards may not meet the data needs of individual practitioners. Similarly, these boards usually do not support the temporary data repository needs of an individual, such as recording reminders, without diminishing their utility for the whole team. Furthermore, the fixed location of

dry-erase boards limits their utility as a reference resource, working memory support, or decision support tool.

Borderline cases exhibit only some of the attributes of the study concept. They are less closely connected to the study concept than are related cases (Walker & Avant, 2005b). Examining borderline cases helps to reinforce the consistency of the model case and clarify the attributes and understanding of the concept of interest. A borderline case of the PCCAT concept is the nursing documentation forms maintained at the patient bedside. Like the PCCAT, these documents are low-tech, lightweight, portable, resilient, easily discarded, require no external power, and easily stored in the medical record when documentation is complete. However, the clinical team determines the data to be recorded and the data configurations depicted by the tool. The inflexible content and format of these documents limit their ability to assist the working memory, decision-making, prioritization, and data needs of the practitioner. Finally, although bedside documentation forms are portable, they are expected to remain at the bedside, thus limiting their use as a reference.

Contrary cases do not display the attributes of the study concept (Walker & Avant, 2005b). An example of a contrary case is the electronic whiteboard, which interfaces with a CIS to display patient information that is refreshed at predefined intervals. Electronic whiteboards are often used in environments involving a very short patient stay and frequently changing patient status such as diagnostic imaging departments, emergency rooms, operating rooms, and post-anesthesia care units. Typically, electronic whiteboards are large, wall-mounted flat screen displays of patient identifiers, arrival times, procedure progression status, diagnosis, and other relevant patient data. Unlike PCCATs, electronic whiteboards are immovable and highly dependent upon technology, require electricity, and have relatively inflexible content. Although somewhat resilient to physical damage, they are vulnerable to CIS downtime. Furthermore, the data cannot be customized to meet the information needs of individual nurses, and the prescribed format, content, and fixed location limit memory, decision, and prioritization support.

Invented cases are alien to the environment in which the study concept is typically found (Walker & Avant, 2005b). One example is the preflight checklist, unique to each aircraft model, that are completed by pilots prior to every takeoff is one example. The Douglas DC-3 (The Aviator Network, 2005) checklist guides the pilot through a prescribed internal and external inspection of the aircraft to confirm that the plane is in working order and ready for flight(Federal Aviation Administration, 1999). Pilots regularly and meticulously observe this preflight procedure to ensure a safe flight and reduce the risk of in-flight problems. While the preflight checklist is an important flight safety measure, it is alien to the world of healthcare and not an instance of the PCCAT concept.

Antecedents and consequences of the PCCAT

Antecedents and consequences can provide insight about the assumptions or variables of the study concept, indicating areas for future exploration. Neither antecedents nor consequences may be defining attributes (Walker & Avant, 2005b).

There are several antecedents to PCCATs. The first is a nursing care relationship with the patient. The second antecedent is the practitioner's need for clinical information about the patient. Data gained from the patient, colleagues, and CIS contribute to preparation of the PCCAT. Figure 5 depicts the antecedents of PCCAT preparation as well as the consequences.
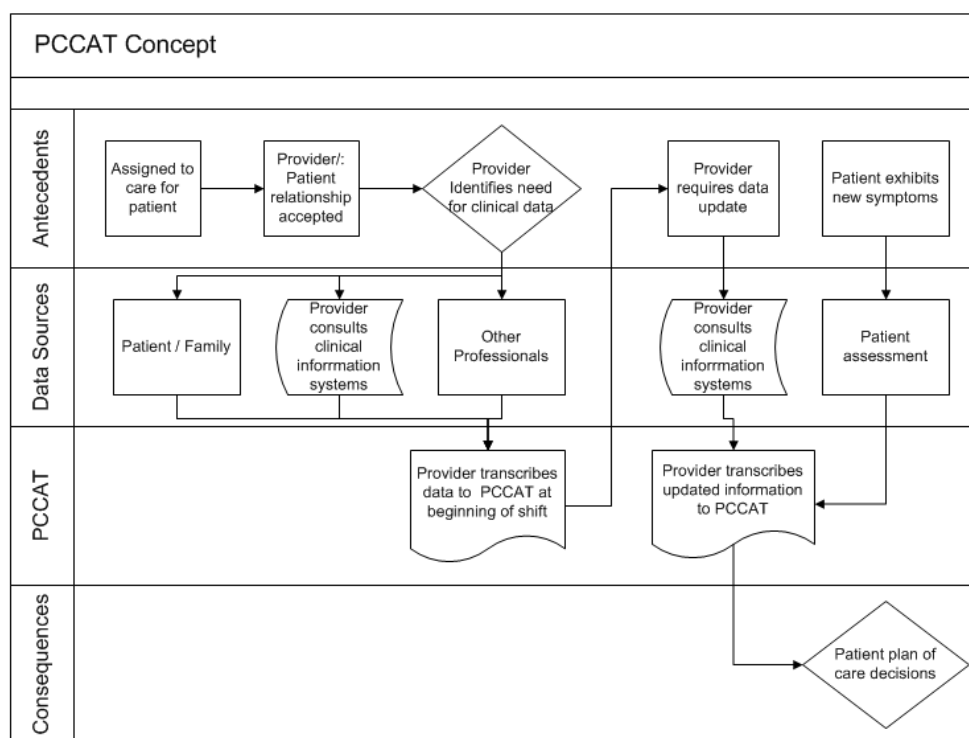
Figure 5: PCCAT Concept Antecedents and Consequences

Consequences of the PCCAT include support of care delivery prioritization, facilitation of data-driven consultation with colleagues, and immediate data availability.

Empirical referents of the PCCAT

Empirical referents are observable phenomena that are used to help identify examples of the concept. Often the defining attributes are also the empirical referents (Walker & Avant, 2005b). For PCCATs, defining physical attributes (portable, lightweight, easily stored, flexible, and easily discarded) and functional attributes (data content defined by the practitioner; reference resource; support of prioritization, working memory, and decision making; and temporary data repository) are the empirical referents.

DISCUSSION

The purpose of this concept analysis was to establish that the PCCAT is a good example of a cognitive artifact. The attributes, antecedents, consequences, and empirical

referents of the PCCAT concept and of the cognitive artifact concept have been explored and clarified through the analysis of model, borderline, and related cases.

Table 4 shows a comparison of the attributes of the PCCAT and cognitive artifacts. PCCATs embody each of the attributes established by Zhang and Patel (Zhang & Patel, 2006) and serve as a personal data record and display of clinical information. Comparison of the antecedents and consequences of cognitive artifacts and the PCCAT, as depicted in Table 5, demonstrates that the criteria are similar. Antecedents reflect the presence of a care relationship, knowledge that guides information seeking behaviors, and information that is complex and of sufficient scope that storage in working memory would be unlikely and would seriously compromise recall accuracy. Consequences of each concept indicate that the practitioner has data available based upon their personal professional needs to aid in consultation, decision making, and working memory. This discussion and concept analysis of cognitive artifacts has been conducted in the context of the clinical domain. However, the analysis can be generalized to the non-healthcare arena.

By carefully examining the defining attributes of the PCCAT and the cognitive artifact, we confirm that the PCCAT is a cognitive artifact in the patient care environment. Attribute comparison is discussed in terms of the clinical domain; however, outcomes can be generalized to the non-clinical domain. Each attribute of the PCCAT and of cognitive artifacts has been successfully cross-mapped. Identifying and clarifying that PCCATs have the same attributes as cognitive artifacts has opened the door to new study dimensions. Future study and understanding of the PCCAT can be guided through application of theories in which cognitive artifacts are a construct. Such studies can begin to characterize how the PCCAT supports cognition, internal representation of knowledge and skills, and external representation of knowledge. Additionally, the role of the PCCAT in collaborative work can also be studied.

Table 4: Comparison of Cognitive Artifact and PCCAT Attributes

Cognitive Artifact Attribute	PCCAT Attribute
Reduce memory load	The scope, complexity, diversity, and temporal nature of data recorded on the PCCAT would be very difficult to store in working memory.
Guide recognition and understanding of inferences, supporting rapid data assimilation	The data the practitioner selects to record on the PCCAT demonstrates recognition and understanding of inferences. This data, in combination with data updates throughout the shift, are evidence that the practitioner understands the patient's diagnosis, clinical condition, and the data necessary to guide the plan of care. Further, the recorded data is a reflection of the user's knowledge and internal representations.
Augment user knowledge and internal representations	The data recorded on the PCCAT at the beginning of the shift, in combination with data updates throughout the shift, are evidence that the practitioner understands the patient's diagnosis, clinical condition, and the data necessary to guide the plan of care. The data selected is a reflection of the user's knowledge and internal representations
Limit abstraction	Each practitioner develops and uses personal codes and formats that have meaning, thereby limiting abstraction for that person. The level of data detail is another indication of the level of abstraction the user prefers. Clinical data recorded on the PCCAT, such as laboratory or diagnostic imaging results, consultation requests, recent symptoms, or medications to be administered, are concrete with limited or no abstraction.
Support user perceptions and cognition without requiring conscious effort	Users record the data they believe to be pertinent. The data selected reflects decisions made and future possible decisions by the practitioner.
Promote more efficient and effective user action	Clinicians are busy and parsimonious relevant to time devoted to data transcription, and are unlikely to record data they do not believe will support care and their care decisions.
Minimize abstraction and support effective decision making	The data recorded and relationships generated support critical thinking and the process of decision making. The individual practitioner based upon personal need for concrete data presentation controls the degree

Cognitive Artifact Attribute	PCCAT Attribute
	of abstraction.
Channel decision making by maximizing accuracy and minimizing user effort	The PCCAT serves as a resource and decision guide based upon the recorded data. The data recorded and added throughout the shift is a reflection of the decision process and also influences subsequent decisions.
Clinical data display prepared for the personal use of the clinician	The PCCAT is a personal document created and prepared by the individual practitioner. A nurse often augments an externally prepared clinical summary in order to assure that it meets with the nurse's internal knowledge representations.

Table 5: Comparison of Cognitive Artifact and PCCAT Antecedents and Consequences

	Cognitive Artifact	PCCAT
Antecedents	1. Direct or indirect patient care relationship 2. Understanding and knowledge of the patient's clinical condition 3. Clinical information about the patient readily available 4. Amount and complexity of data precludes accurate storage in short-term memory	1. Created in response to a patient/care provider assignment 2. Intention to serve as the care provider 3. Intention to provide care creates the need for clinical information 4. Scope, complexity, diversity, and temporal nature of data recorded on the PCCAT would render it difficult to store in working memory
Consequences	1. Ability to access, on demand, clinical data defined as necessary by the practitioner 2. Ability to reference clinical data during consultation with colleagues 3. Support for decision making through data context and structure.	1. Ability to more efficiently prioritize care delivery 2. Support for data-driven colleague consultations 3. Ability to access data on demand 4. Support for plan of care decisions

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Research Methods: Exploring Cognitive Work

Research Methods: Exploring Cognitive Work

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ABSTRACT

The purpose of this paper is to describe a complex, cross-sectional, multi-method approach to study of personal cognitive artifacts in the clinical environment. The complex data arrays present in these cognitive artifacts warrant the use of multiple methods of data collection. Use of a less robust research design may result in an incomplete understanding of the meaning, value, content, and relationships between personal cognitive artifacts in the clinical environment and the cognitive work of the user.

INTRODUCTION

Nurses are knowledge workers and dependent upon a complex array of data to guide patient care decisions. The decisions nurses make are the result of a complex interplay between the nurse's personal experiential knowledge and the array knowledge present in the external environment that they consult prior to creating or modifying the patient's plan of care. To support assimilation of their personal knowledge and the external knowledge, nurses generally use or create personal cognitive artifacts to summarize what they know and have learned about the patient. Cognitive artifacts are defined as objects or software applications that support and influence our thinking, memory, problem solving, and reasoning (Nemeth, O'Connor, Klock, & Cook, 2006; Norman, 1991).

The personal cognitive artifact, or PCA, that nurses prepare has several important purposes. The data recorded on the PCA provides the nurse with 'just in time' data recall and reduces working memory burden. The PCA supports data organization and task prioritization, offering a visual representation of the work to be done and the flow of the day. The organization of information on the PCA has value and meaning for the individual nurse and supports trending, reflection, and reflexivity regarding care plan decisions.

The PCA, while important to nurse work, is not without risks. In many cases the PCA is prepared or amended through transcription of data, incorporating associated and attendant risks. Preparing the PCCAT is time consuming, and the timeliness of information update during

the course of the day is dependent on when the nurse is able to access the necessary resources.

The complexity of cognitive artifacts such as the PCA, and the multiple ways in which these cognitive artifacts are used, requires a complex multi-method study approach. A singular approach would provide an incomplete understanding of the meaning, value, content, and relationships of the PCA and the cognitive work of the nurse. We wanted to develop a robust understanding of the PCA, incorporating the subjective perspective of the practitioner and the conclusions of the investigator (Nemeth, Cook, O'Connor, & Klock, 2004).

We believe that the methods discussed in this paper should be used when examining cognitive artifacts in a complex clinical environment. Identification of external knowledge representations in the clinical environment enabled us to define the scope of our study domain. Internal knowledge representation was examined by shadowing subjects and through the use of private interviews. While we could not directly measure our subject's cognition, we indirectly explored their cognition by asking them to use reflection and reflexivity to help them share the value, purpose, and meaning of their PCA. These methods were enhanced by iterative analysis, allowing each phase of data collection to provide guidance to subsequent phases while informing previous phases. Triangulation was inherent to this analytic process. This paper discusses the cross-sectional, multi-method approach we designed to study the knowledge representations and structures used by nurses.

CONCEPTUAL FRAMEWORK

We developed a conceptual framework to guide the research of cognitive artifacts in the clinical environment. The conceptual framework is grounded and guided by two theories, Distributed Cognition and Constructivism (see Figure 1). Each theory speaks to the relationship of an individual to the world in which he or she lives, practices, and interacts. The relationship of an individual to the environment is enriched, reinforced, modified, and/or changed by the information available in the external world.

Figure 1: Conceptual Framework
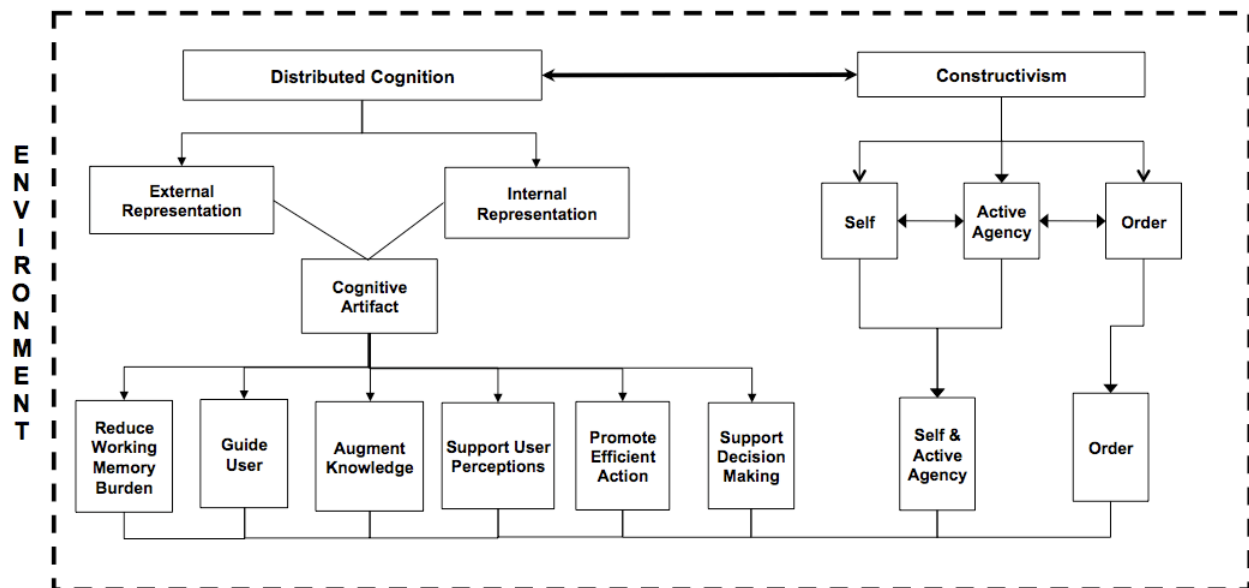
Distributed cognition recognizes that knowledge and understanding evolve through the continual interaction of an individual's experiential knowledge, or internal knowledge representations, with information resident in the environment, or external knowledge representations. External knowledge representations include cognitive artifacts, technology, equipment, other individuals, or groups, geographic layout or floor plans, the roles and relationships of other individuals or agents, policies, procedures, and technology, which individually or in combination offer information, knowledge, experience, and perspective. As individuals, we assess the information presented by external knowledge representations within the context of our internal knowledge representations, and make decisions regarding the veracity and utility of the external data. Decisions about the external data result in 1) affirmation of our own knowledge, 2) rejection of the external data because it differs from what we know and is without sufficient evidence to promote acceptance, or 3) modification of our current knowledge in light of the evidence associated with the new knowledge present in the environment. The result of the interaction between our internal knowledge representations and external knowledge representations is a

cognitive artifact, often in the form of a document such as the PCA (Hollan, Hutchins, & Kirsh, 2000; Zhang & Patel, 2006).

Distributed cognition also speaks to how broadly external knowledge representations are dispersed in the environment. The more dispersed the external knowledge representation resources, the greater the effort an individual must expend to gather and assess those resources. While dispersion of external representations is a naturally occurring phenomenon, this dispersion can increase the cognitive work of the individual as he/she seeks to create a synthesis or summary for personal cognitive purposes. As the number of locations and sources of external data increases, cognitive work increases, and the burden of clinical data synthesis and 'sense-making' increases.

Constructivism suggests that understanding is molded by the interpretive knowledge and experience of the individual. The individual is shaped by a need to be proactive (active agency), and the need to identify patterns and meaning (order) in the external world. Being proactive and discerning order offer an individual a sense of mastery, control, and belonging, important dimensions of self. The intersection of Distributed Cognition theory and Constructivism theory provides the conceptual framework for research related to cognitive artifacts embedded in complex clinical domains.

METHODOLOGY FRAMEWORK

Qualitative research methods were chosen to conduct this exploratory study. The processes of development and use of a PCA, and the meaning of the PCA for the clinician, typically recommend the use of qualitative research methods (Green & Thorogood, 2004). We wanted to conduct an in-depth study about the processes used to develop the PCA, the context when the practitioner used the cognitive artifact, and the practitioner perceptions of the use, value, and purposes of the artifact.

Study of the content, relationships among the data, and the evolution of the PCA through the shift pointed to a grounded theory approach to data collection and analysis. Ethnographic

observations and interviews were central to understanding how the practitioner constructed the PCA, and when, why, and how the PCA was used throughout the shift. Phenomenology constructs guided the interviews with the practitioners to explore and understand their perceived value of the PCA and their personal sense of connection to the PCA. Employing these multiple methods demanded an iterative, cross-sectional analytic process that guided subsequent data collection and informed analysis of earlier data, continually refining our understanding and conclusions. Figure 2 depicts the three foci inherent to study of this class of problems: external knowledge representation, internal knowledge representation, and cognition, and the methods we employed.

Figure 2: Methodology Framework

Model Created by Adol Esquivel, PhD, MD
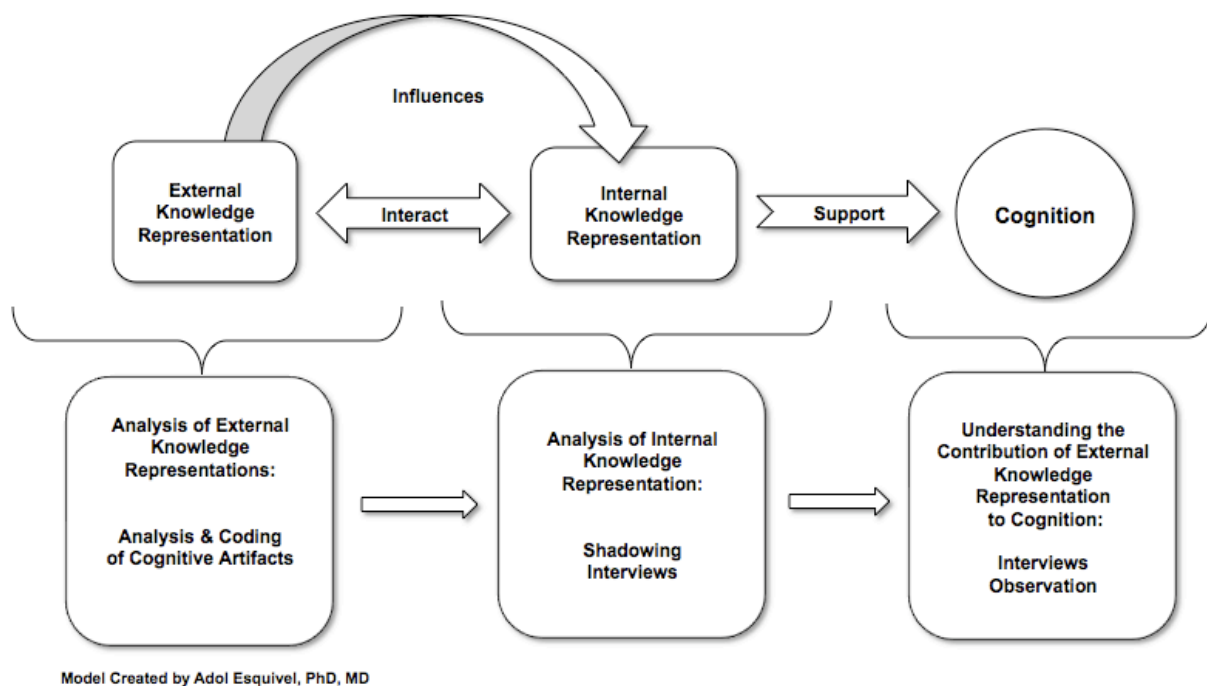
Study of External Knowledge Representation

Study of external knowledge representations requires reflection and thoughtful analysis of the external knowledge representation factors to be included in the study. Considerations may include cognitive artifacts, technology, equipment, other individuals, or groups, geographic

layout or floor plans, the roles and relationships of other individuals or agents, policies, procedures, and technology. The scope of domain analysis should be guided by the research goals, and will be influenced by available resources. The goal is to understand as fully as possible the factors that influence the content of knowledge representations and structures.

We limited the study of external knowledge representations in our study to the cognitive artifacts consulted by the nurse. Examples of cognitive artifacts integral to the work nurses in our study included intake & output flowsheets, the medication administration record (MAR), selected dictated records in the EMR, and lab results, and the nurse summarized data from these artifacts on the PCA.

Study of the PCA included how the nurse chose to configure the recorded data. How each user chooses to configure data may reveal the needs of that individual for data inclusion, data relationships, tabular or graphic representations, and other formatting features. Spatial arrangement of data elements, clustering of data, serial data, temporal data, the use of color, graphs, charts, and marking patterns (e.g. slashes, check boxes, strike through) provide information about how presentation of data adds meaning for the individual. These configuration elements are fingerprints that point to how the data is used, what data is meaningful, how the subjects process data, and how configurations may be important to cognitive work (Card, Mackinlay, & Shneiderman, 1999; Zhang, Johnson, Malin, & Smith, 2002).

For example, our recent study of nurse PCAs disclosed that some nurses prefer serial lab values, while other nurses prefer to only be made aware of abnormal values. Exploration of this difference revealed that the group preferring serial data wanted to be aware of the trend of the patient's values and to respond promptly to questions about lab values when the physician team rounded. The nurses who preferred only abnormal data tended to focus on the lab values associated with standing orders to administer an electrolyte when results were below a threshold value.

Analysis and study of external knowledge representations may provide evidence of collaborative cognitive work, demonstrating the integration of contributions by various individuals to the work of the group. Examples of collaborative artifacts are whiteboards that provide the status of work pending, in progress, and completed. Another example, dashboard reports, is the result of the collaborative work of a group or groups, and responsive action plans are often collaboratively designed and executed.

Study of user access of external knowledge representations may answer questions about what information is important to the subject, how they may use the information, the importance of types of information formatting, and the presence of collaboration with other agents. While some questions are answered, new questions arise about the nature of the PCA created by subjects. New questions may include who creates a cognitive artifact in the clinical environment, and how often subjects use a cognitive artifact. Each of these questions informs and influences the data collection processes of a multi-method research design.

Our analysis of PCAs created by nurses resulted in the development of a taxonomy and an ontology of the PCA. Exploring the content domain of the PCA prompted new questions that guided or modified data collection plans during subsequent phases of our multi-method study. For example, most nurses in our study recorded the date of the patient's last bowel movement. Investigation during subsequent phases of data collection disclosed that nurses are accountable for management of standing orders for bowel elimination. The nurses understood the importance that the patient avoids straining, to avoid the risk of increased intracranial pressure in the neurosurgery patient, and possible tears and bleeding in the hematology patient with few or no platelets to support coagulation. Hence, the presence of the date of the last bowel movement was explained and understood.

Internal Knowledge Representation

Internal knowledge representation can be discerned through observation and dialogue with the subject. Indicators of the subject's knowledge may be discerned through the identification and assessment of indirect factors, such as conclusions, decisions, or care plans developed in response to data. Shadowing subjects in the work environment presents an effective method to observe behaviors, discuss issues, and clarify perceptions.

Data collection during shadowing may be recorded in several ways, using a variety of tools. One of the most common methods is the investigator's use of open-ended, hand-written field. Some settings lend themselves to the use of prepared checklists. In addition field notes, the investigator may choose to unobtrusively audio record activities. Photography may also be a useful adjunct to field notes and digital recording (Morse & Richards, 2002).

The heuristics subjects use to identify data that they add to their PCA offers an indication of the subject's thought processes as well as expertise. Notations may be an indication of temporary documentation until the permanent record is available. Notations may also represent data the subject wants to assure is available at a later time, eliminating the need to store the information in memory. Notations may also provide indications of expert knowledge as subtle changes are noted and recorded for later consultation or reflection.

Shadowing offers the opportunity to explore the cognitive work of the subjects with a different lens, adding detail and context to questions that developed during PCA content analysis. In the natural work setting the investigator can observe for a number of factors, such as: 1) subject activity immediately prior to interacting with their PCA; 2) identification of concurrent activity while interacting with the PCA, such as talking with others, telephoning, writing, reviewing other documents, reviewing a computer screen; 3) activity immediately after completing PCA interaction; and 4) observing for notes added to the PCA during interactions. Other factors of interest are periods of peak use and diminished use of data and PCA, and how

the subject integrates the information recorded on the PCA into their overall workflow, organization, and prioritization.

A benefit of shadowing is the opportunity to talk with the subject, asking questions about reflections, intentions, perceived value, usefulness of various cognitive artifacts in the environment, and the influence of cognitive artifacts and their PCA to care plan formulation or changes in the plan of care. Shadowing provides the investigator an excellent opportunity to confirm or validate perceptions generated while shadowing or developed during document analysis, enabling modification, confirmation, or abandonment of prior conclusions or assumptions (Angrosino, 2005; Green & Thorogood, 2004). However, some shadowing experiences may not lend themselves to conversation with the subject. This may be the result of the pace and urgency of work-related activity, or may be related to environmental factors such the absence of quiet moments or the privacy to talk.

Shadowing enables the investigator to observe when, where, how, and possible usage patterns of the PCA, as well as factors that promote use. Thoughts, perceptions, concerns, and tentative conclusions can be discussed with the subject. Understanding how, when, and where documents are used increases understanding of the contribution of the documents to the cognitive work of the subject.

Shadowing adds context, meaning, value, and purpose to what is already known about a cognitive artifact in the clinical environment, enabling the information gained during PCA analysis and coding to come alive in the clinical setting. The perceptions of the subjects add another dimension to the importance, value, and meaning of the artifact. The researcher is able to gain an understanding of how and when the PCA is used, awakening an understanding of the strengths and limitations of the PCA. Shadowing enriches data collection by providing glimpses of the interaction between external knowledge representations and the subject's internal knowledge representations, and how external knowledge representations influence the internal knowledge representation.

Shadowing is also likely to raise new questions. How, when, and why the document is used will vary between subjects, prompting the investigator to ask the subject to share meaning, purposes, and reflections as they work with the PCA, cognitive artifacts, explore the intentions of the subject and gain additional insight into internal knowledge representation.

The shadowing experience during our study of the PCA in the clinical environment disclosed almost immediately that the dispersion of external knowledge representations created a barrier to developing a comprehensive summary of the patient's clinical condition and the plan of care. The distributed cognition that we observed added important contextual data and allowed us to interpret the meaning of the PCA with new understanding. Broadening our data collection to include external knowledge representations in the environment, we elicited insights and perceptions about the distributed cognition the subjects experienced. Recognition of the importance of distributed cognition to our study, and how this discovery modified our perspective of the environment, is an exemplar of the importance and value of a multi-method approach in the study of complex knowledge structures.

User Reflection & Reflectivity as a Window on Cognition

We were not able to directly study the cognition and cognitive processes of our subjects. We therefore sought to identify surrogates of the highly complex topic of cognition, and selected user reflection and reflexivity as they spoke about and described their experiences. The perspective of the subject is a critical dimension to understanding the contribution of personal cognitive artifacts to how subjects thought about, made decisions about, and planned the care of patients. We chose to interview subjects, seeking to add a richer dimension to our understanding of personal cognitive artifacts as informed by PCA analysis and shadowing.

Structured and semi-structured interviews, in a setting that supports thoughtful reflection, enable clarification of information previously gathered. Data gathered during shadowing events can be revisited to determine if the subject's perceptions have changed or if responses are consistent. Interviewing creates a stage for subjects and allows the investigator to elicit the

subject's opinions, and test conclusions and interpretations. Interviews also support comparison and contrast of responses from subjects, soliciting impressions about the perceptions or insights generated during data collection.

Interviewing in our study was divided into two phases. The semi-structured questions of the first phase probed for the subject's reflections about the value and meaning of the PCA they used in the clinical environment. The second phase interviews occurred in response to a simulated clinical scenario.

The first interview included questions similar to the questions asked during shadowing, seeking to determine if the subject's perceptions had changed. We also cross-referenced thoughts provided from other study participants to determine if those ideas and concepts resonated with the subject. The primary focus of this interview was to explore the value, purpose, and meaning of the PCA for the nurse. Our subjects often responded very passionately as they described the value and meaning of their PCA, and the role of this document in their practice. The interviews also allowed us to continue to explore how specific types of external knowledge representations were useful or supported reflection and reflexivity of the individual.

The second interview phase involved simulated clinical scenarios. Subjects were asked to review the data and identify data missing in the scenario that they would find important to have available. We also asked them to identify data present in the scenario that was highly useful, and data that they did not find meaningful. For example, we added psychosocial data to the scenario, information that was rarely present on the PCAs that we had analyzed and coded. Responses during the scenario clarified why this data was infrequently present on the PCA, and how and when such data was communicated in the clinical environment. We then discussed their decisions and the rationale for their recommendations. The process of critiquing the clinical scenarios provided reinforcement of data collected during previous stages of data collection, and also enabled the subject to elicit and share new reflections or perceptions.

DISCUSSION & CONCLUSIONS

The cross-sectional multi-method data collection processes we have discussed were used to study a class of problems, personal cognitive artifacts in the clinical environment. The study included document analysis, shadowing, interviews, and a clinical scenario. Each method of data collection provided robust and dense data about the personal cognitive artifact created and used by nurses. As the data were analyzed, new questions arose, and many of those questions could not be explored using the current method. For example, identification of the presence or absence of specific types of data during analysis of PCA content domain most likely could not be adequately addressed through analysis of additional; it required dialogue with the nurses. Another example, understanding the value and meaning of the PCA to the nurse, was only partially understood through shadowing the nurse; this data could only be elicited through the dialogue of an interview.

Each phase of data collection informed the previous phase and also provided structure and context to the next phase. An important dimension of a multi-method study is the iterative nature of data collection and analysis. Data collection is not linear; as new questions arise, the investigator loops back and collects additional data to address the new questions. The phases that we have outlined are interactive, at times prompting that data collected in a prior phase be revisited, with possibly additional data collection, to help address a new question.

The multi-method research design we describe can be translated to other instantiations of cognitive artifacts in the clinical environment. The methods also lend themselves to other practice disciplines and multidisciplinary groups. The additional time and effort required for use of this multi-method framework is more than offset by the comprehensive understanding of the meaning and contribution of cognitive artifacts to the cognition of users.

Outcomes from study and analysis of cognitive artifacts include a rich and detailed understanding of this complex domain, including the domain content and context; the heuristics

users employ to create the artifact; formatting and configuration preferences of the user; external knowledge representations consulted during creation and amendment; when, how, and where the cognitive artifacts are consulted by the user; and how the cognitive artifact influences cognition. This analysis should clearly identify the value and meaning of the cognitive artifact to the user. A clear understanding about how cognitive artifacts are created and used will inform the designs to improve or develop alternatives to these cognitive artifacts.

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Making the Cognitive Work of Registered Nurses Visible

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ABSTRACT

Purpose: Knowledge representations and structures are created and used by registered nurses to guide patient care. Understanding is limited regarding how these knowledge representations, or cognitive artifacts, contribute to working memory, prioritization, organization, cognition, and decision-making. The purpose of this study was to identify and characterize the role a specific cognitive artifact knowledge representation and structure as it contributed to the cognitive work of the registered nurse.

Methods: Data collection was completed, using qualitative research methods, by shadowing and interviewing 25 registered nurses. Data analysis employed triangulation and iterative analytic processes.

Results: Nurse cognitive artifacts support recall, data evaluation, decision-making, organization, and prioritization. These cognitive artifacts demonstrated spatial, longitudinal, chronologic, visual, and personal cues to support the cognitive work of nurses.

Conclusions: Nurse cognitive artifacts are an important adjunct to the cognitive work of nurses, and directly support patient care. Nurses need to be able to configure their cognitive artifact in ways that are meaningful and support their internal knowledge representations.

INTRODUCTION

Complex arrays of data are essential to support the cognitive work of knowledge workers. Registered nurses (RN) are knowledge workers who are dependent upon a complex array of clinical information to inform patient care decisions. The decisions RNs make are the result of an intricate interplay between the nurse's knowledge and experience, or internal knowledge representations, and data present in various forms and locations in the environment, or external data representations. This interplay contributes to the development, implementation, and modification of the plan of care for a patient. To assist in integrating this information, the RN creates a knowledge representation, a cognitive artifact, which summarizes the structure of his/her internal and external knowledge representations. Once created, the cognitive artifact plays a principle role in the cognitive work processes of the nurse. The purpose of this paper is to study the role a specific cognitive artifact knowledge representation within the cognitive work of the RN.

Cognitive artifacts are defined as objects or software applications that support and influence our thinking, memory, problem-solving, and reasoning (C. Nemeth, O'Connor, Klock, & Cook, 2006; Norman, 1991). Cognitive artifacts are part of daily life, and examples include appointment calendars, grocery lists, project plans, task lists, and desktop icons. A cognitive artifact may be for the personal use of an individual, while in other situations the cognitive artifact may be developed and amended by members of a team and used to guide and monitor the collective work of the team, such as white boards or staffing rosters (Bang & Timpka, 2003; Xiao, 2005). The cognitive artifact that is the subject of this research is a document that is created and/or amended by a RN for personal use as the nurse delivers patient care during a work shift.

RNs record clinical information about the patient on their personally created cognitive artifact (PCCAT). The clinical information is selected as a result of the interaction between data present in the environment (external representations) and the experiential knowledge of the

nurse (internal knowledge representation). Figure 1 is a model that depicts the interplay of

examples of external and internal knowledge representations, and the PCCAT the nurse

develops in response to the interplay. The data the nurse selects to record on the PCCAT is a

reflection of: 1) identification of data that is important to the care of a patient at this point in the

patient's care path, 2) identification of data that has possible implications for the patient's plan of

care, and 3) identification of data that requires follow-up and that may result in modification or

continuation of the patient's plan of care. The data the RN typically records on the PCCAT

includes the patient's diagnosis, reason for admission, past medical history, recent medical or

surgical interventions, symptoms and the effectiveness of symptom management interventions,

assessment data, fluid balance, IV management, and other data important to the plan of care.

Many RNs also add the schedule of medications to be administered during the shift, including

drug, dose, and time of administration. With addition of the medication schedule, the PCCAT

may, for some nurses, supplant the medication administration record (MAR) as the resource for

medication administration throughout the shift. Upon completion of initial notations and data

entry, the PCCAT is generally the nurse's constant companion for the remainder of the shift.
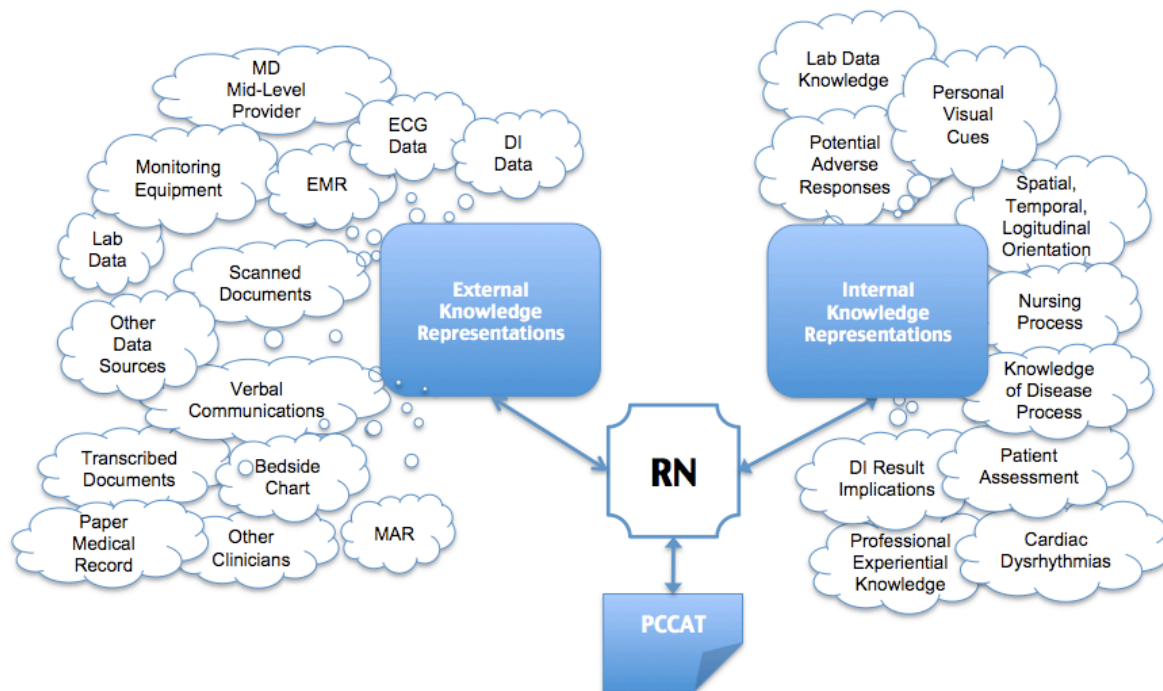
Figure 1: *Model of PCCAT Development Using Examples of External & Internal Knowledge Representations*

The model depicted in Figure 1 is indicative of the concept of distributed cognition. Distributed cognition positions individual cognition as a composite of the experiential knowledge of the individual in combination with information in the environment, such as other individuals, groups, cognitive artifacts, and other agents. Distributed cognition posits that we are continually evaluating our internal knowledge with the information available in the current context. The evaluation process results in reinforcement of our current knowledge, rejection of our current internal knowledge for the new external knowledge, or modification of our internal knowledge in response to evidence available in the environment (external knowledge) (Hutchins, 1995).

As Figure 1 depicts, the interface between the external and internal representations of the nurse, and between the nurse and the PCCAT, is dynamic as each component of distributed cognition iteratively influences the other. From this continuing interface the nurse's decisions regarding the patient's care plan are reinforced or modified. For example, the patient may share

with the nurse that he has been having muscle spasms and leg cramps for the past few days, but has not shared this information with the physician. Noting this symptom on the PCCAT, the nurse checks to see if the patient's lab results have been reported. The nurse notes the potassium level is slightly below the lower limit of the normal range, records this on the PCCAT, and makes a note to discuss the patient's symptoms with the physician on rounds.

The value of cognitive artifacts such as the PCCAT is intrinsic for the nurse, and the absence of the PCCAT would result in significantly diminished understanding and insight regarding the clinical condition of the patient, and the resulting plan of care (Zhang & Patel, 2006). While the PCCAT serves as a data repository of indicators of the patient's clinical condition and progress, the PCCAT also supports working memory (Patel, Kushniruk, Yang, & Yale, 2000; Zhang & Norman, 1994), information visualization (Card, Mackinlay, & Shneiderman, 1999), and other cognitive work of the nurse.

Working memory, or intentional retention of data in memory to support cognitive activities, is aided as the PCCAT offers a 'just in time' data recall resource, minimizing the need for cognitive attention processes to maintain data in memory (Baddeley, 2003; Kane, et al., 2004; Miller, 1994; Tuholski, Engle, & Baylis, 2001). Notations on the PCCAT for later reference or reminder purposes also evidence working memory support. The PCCAT can minimize the consequences of interruption serving as a resource to recall cognitive or task activities immediately prior to the interruption (Brixey, Robinson, Turley, & Zhang, 2007; Laxmisan, et al., 2006).

An example of visualization support is the nurse's incorporation of personally meaningful patterns and codes that support trending, reflection, and reflexive evaluation of data (Schon, 1983). Spatial, graphic, longitudinal, or temporal data relationships on the PCCAT may further support cognition and decision-making. Nurse may also add notations to indicate that data recorded on the PCCAT has been transcribed to the permanent medical record. Figure 2 presents a PCCAT after the completion of a work shift. This figure demonstrates the use of

spatial orientation (e.g. assessment data on the right, medication information on the left), longitudinal lab results, chronologic medication schedule, slashes that serve as personal visual cues, and general notations with meaning to the nurse.

Another purpose of the PCCAT is to present an overview of the care delivery tasks to be completed for the patient or patients assigned to the nurse for the shift. This overview enables the nurse to organize tasks and prioritize care delivery tasks for a patient and among several patients.

Figure 2: Example of a PCCAT with temporal, longitudinal, spatial, and personal visual cues

While important to the cognitive work of registered nurses, the PCCAT is not without patient safety risks. This cognitive artifact is often prepared or amended through data transcription from various resources (see Figure 1). Transcription, the process of copying data from a source to another location, incorporates the inherent risks of omission, redundancy,

transposition, and recording information for the wrong patient; each risk compromises patient

safety and may result in harm to the patient. Data transcription error rates ranging from 0.5% to

8.2% have been reported (Galloway, Woods, Whitehead, & Stainsby, 1999; Hogan & Wagner,

1997; Wagner & Hogan, 1996). Prevention of patient harm or injury, to include reduction of

transcription as a source of error, is central to the healthcare agenda of the United States and

many other countries (Institute of Medicine, 2000, 2004a, 2004b).

Our review of the literature found no published studies of nurse cognitive artifacts that

are used to support cognition through the course of a work shift. Published research reports of

registered-nurse-generated cognitive artifacts are limited to discussion of the handoff report

between nursing shifts (Myny, Verdonck, Danneels, Verwaeren, & Decruyenaere, 2005; Strople

& Ottani, 2006). These researchers did not report how or if these hand-off reports were used

after completion of shift report.

Studies of collaborative cognitive artifacts and the interdependence of agents in

managing work have been reported (C. Nemeth, O'Connor, Klock, & Cook, 2005; C. Nemeth, et

al., 2006; C. P. Nemeth, Cook, & Woods, 2004). These studies, while providing important

insights regarding the collaborative work of more than one individual, do not address the

cognitive artifact developed for the singular use of an individual. Krippendorff and Butter, in

discussing cognitive artifacts, suggest that, in an effort to understand how people relate to

artifacts, we need to focus on the processes for which the artifacts were created rather than the

artifact itself (Krippendorf & Butter, 2007) (see Figure 2). The purpose of this paper is to study

the role a specific cognitive artifact knowledge representation, the PCCAT, within the cognitive

work of the RN.

METHODS

Study design

A multi-method qualitative design, employing ethnographic, phenomenologic, and grounded theories, was developed for this study. The methods employed for data collection were reported previously (McLane, Esquivel, Engebretson, et al.).

Subjects

Registered nurses who spent a minimum of 50% of their worked time in direct patient care were eligible to participate in the study. The principle investigator recruited nurses by attending staff meetings to explain the study purpose, and desired outcomes, data collection methods, risks, benefits, and expectations of participation in the study. Staff expressing interest in participation received more detailed information about the study. A total of 28 nurses consented to participate in the study.

Ethical Approval and Informed Consent

Prior to study implementation, approval was obtained from the Institutional Review Board (IRB) of the study hospital and The Committee for the Protection of Human Subjects of the university.

All RNs expressing interest in participation were fully informed of the purpose, data collection methods, expected outcomes, potential risks, and potential benefits of the study. A signed informed consent was used. Study participants were also informed that they could withdraw from the study at any time without prejudice. Methods to assure the confidentiality of the protected health information (PHI) of patients and to protect the identity of patients and staff were explained. Study participation was initiated after written informed consent was obtained from each nurse.

Setting

The study was conducted at a comprehensive cancer center located in the southern region of the USA. At the time of data collection, the cancer center was in the process of transition from paper documentation to an electronic medical record. A convenience sample of

three inpatient units was selected: a neurosurgery and rehabilitation unit, a thoracic surgery unit, and a hematology/stem-cell transplant unit.

Data Collection

Data collection was completed between July 2008 and in March 2009. The multi-method approach included: 1) analysis and coding of completed PCCAT documents as examples of external knowledge representation; 2) shadowing nurse participants in the work setting to identify and explore internal knowledge representation and nurse interaction with additional external knowledge representations; and 3) interview of nurse participants to elicit reflections on use of the PCCAT, to discuss the contribution of various external knowledge representations to their personal cognitive processes, and to explore the nurse's perceived value and meaning of the PCCAT. Issues related to the taxonomy/ontology of the PCCATs are presented elsewhere (McLane, Esquivel, Engebretson, et al.). This paper reports the results of the shadowing and reflective interview data.

Data collection during shadowing was a written chronology of actions and interactions by the nurse. The investigator clarified interpretations, conclusions, and questions during quiet moments. The nurse often supplemented her actions by sharing personal reflections and explanations with the investigator.

A second phase of data collection involved interviews with individual subjects. The interviews, which were conducted in a quiet location off the patient care unit, incorporated a prepared script of questions. Insights, reflections, and personal perceptions volunteered by the nurse augmented the prepared questions during several interviews.

Data Analysis

Data analysis was completed using triangulation, comparing data between and within methods. Triangulation offered a means of increasing confidence or faith in the data and the interpretations generated from the data by clarifying and refining insights and conclusions.

Triangulation between the shadowing experiences and the staff interviews clarified the investigator's interpretations and understanding (Green & Thorogood, 2004).

The field notes during shadowing and digitally recorded interviews were transcribed using word-processing software. The transcribed documents were uploaded into NVivo 8© (ORS International, 2009) for analysis and coding. A priori categories were developed for data analysis and coding, and augmented as new themes evolved. Codes included indicators of cognitive work, such as recall, reflection, or decision-making, the nursing process, care delivery functions, and communication. Coding was completed using an iterative process to ensure that all data was coded consistently and that all appropriate codes were identified. Table 1 is a list of parent codes used for data coding.

Table 1: Parent Codes Employed for Shadow and Interview Analyses

Code	Definition
Care Delivery	Specific patient care interventions provided by the nurse or delegated to another nursing team member
Cognition	Indicators of cognitive activity or support
Communication Tools	Tools used to exchange of information between 2 or more care providers
Culture	Examples of organizational culture
Event	Key events that occur during the shift (e.g. shift report, physician rounds)
Information Resources	Cognitive artifacts the nurse can and does access to gather needed data
Nursing Process	Nurse engaged in the nursing process (assess, diagnose, plan, intervene, evaluate)

Organization	Influence of PCCAT on completing nursing care tasks
Patient Safety & Error Prevention	Action by nurse to reduce the risk of error
PCCAT	Value, use, meaning, and preparation of the PCCT and spreadsheet
People	Individuals and roles that nurses interact with through the course of patient care
Personal Characteristic	Observed characteristic demonstrated by the nurse (e.g. expert knowledge, information seeking behavior)
Recommend Change in Care Orders	Nurse recommendations that would result in a new, modified, or discontinued patient care order
Value of Experience	Examples of the value of clinical experience

Many of the parent codes have sub-codes, or children. The decision to create sub-codes was guided by the topic and the frequency that a topic was coded within a parent category code.

RESULTS

Study participant demographics

Twenty-five of the 28 nurses that signed informed consent participated in at least one phase of data collection; three nurses were unable to participate after providing consent (extended maternity leave; transfer to a non-participating unit; and increase in non-patient-care job responsibilities). Table 2 indicates the demographic makeup of the study participants. While there was considerable variance in mean years of nursing experience between and within the units, the sample sizes were too small to correlate data results with years of nursing experience.

Table 2: *Study Participants*

Unit	# RN	% 7A-7P	Nursing Experience (Yrs)

	Subjects	Shift	Mean	Standard Deviation
Hematology/Stem-Cell Transplant	9	22%	7.3	5.3
Thoracic Surgery	10	30%	10.6	10.1
Neurosurgery & Physical Rehab	6	33%	13.9	10.9
Total	**25**	**28%**	**10.2**	**8.9**

The RNs and nursing leadership were eager for an automated version of the PCCAT. A spreadsheet program was developed and implemented as an alternative to the hand-written PCCAT prior to implementation of this study. The spreadsheet format was intended to serve as a bridge solution until a clinical summary product was available from the future EMR. The nurse caring for the patient updated spreadsheet for the nurse about to assume care responsibility. Data included the patient's reason for admission and current condition, pertinent history, procedures scheduled or completed, lab and diagnostic imaging results, fluid balance, patient symptoms and symptom management results, and other pertinent information. In most cases the nurse receiving report amended the spreadsheet report, adding data they believed was missing and important to the patient's care plan. Most nurses also added the medications to be administered for the shift. Eight of the 25 nurse participants (32%) prepared a separate personal PCCAT, transcribing data from the spreadsheet and other data resources to a personally configured template (see Figure 2).

Creation of PCCAT

Observing nurses as they prepared the PCCAT disclosed the scope of distributed cognition on each unit. The nurse consulted the spreadsheet summary from the previous shift, and many of the examples of external knowledge representation depicted in Figure 1. The PCCAT the nurse created for the shift was a composite of data from the spreadsheet summary and data from external representations.

When data are proximate, as opposed to being located in various external locations, interpretation and understanding the meaning of the data is more likely. One of our study participants succinctly summarized how the PCCAT may overcome some of the problems of distributed data, when he said *"because it's easy to miss this over here or that over there when you're looking in 2 different spots. When it's all brought together in the same area, it's like looking at a photo. It's like, "Ta-dum!" There it is."*

All of the nurses that were shadowed reviewed the MAR (medication administration record) at the beginning of the shift. Eight (57%) nurses recorded the scheduled time of medication administration on the PCCAT. Eight (57%) recorded the name of the scheduled medication. Five (36%) of the nurses shadowed indicated that they used the PCCAT as their MAR for scheduled medication administration. In a few instances, nurses who stated they only used the MAR for medication administration were noted to use the PCCAT as the medication data source in isolated situations.

One nurse summarized why she needed to transcribe medications to the PCCAT, stating that the multiple pages of the MAR (generally 10 – 25 pages) do not provide her with a comprehensive overview of the scheduled medications for her assigned patients. She indicated she *"wants to see the whole day every time I look at my [PCCAT]".* This enables her to assess for drugs that are incompatible when given concurrently, and to combine administration times where appropriate to support other care delivery responsibilities. For example, she *will "hang an IV medication early and program the pump to begin administration at the appropriate time if I know I will be tied up in another patient's room for an extended period".* In other instances she

indicated that she may, for example, combine the 9:00 a.m. and 10:00 a.m. medications if the care demands of her patient assignment warrant.

Flow of the Day & Organization

The PCCAT supports information visualization by enabling the nurse to "see" the work that needs to be completed, assess the complexity of the work, gauge the time necessary to complete the necessary care delivery tasks, organize that work, and finally prioritize the work. The PCCAT serves as a critical tool for most nurses, enabling them to assess care delivery tasks for the individual patient and collectively for all patients in their care. The PCCAT supports reflection and decisions about the timing of tasks and determine which tasks can be completed concurrently.

One nurse stated: *"…[I am] organized by time with all three of my patients where I can see [them] across [the day], so I'm able to see, okay, well, this patient has meds at this time; this patient has meds at this time; and I can organize who I'm going to see first. Or I need to get this done, and I don't have anything [that] this patient [needs at the moment]… It just helps me with the flow of my day [to] know where I need to be when."*

"I go wherever clinically I know I need to go first, but [the PCCAT] also helps me stay organized with the amount of stuff that I have to do with each patient, where I should go first…".

In another instance, the PCCAT was described as *"an ever-flowing, ever-evolving thing throughout the day. It helps me stay on track. It's a very complex to-do list."*

Another nurse characterized the importance of the PCCAT to her organization by sharing that *"It's kind of like your own private assistant that goes behind you and keeps you in line…"*

"It's like a roadmap that kind of tells me how my night is going to go in terms of medication or anything I have to do (for) the patient…"

"My [PCCAT is] my way of organizing, it's a visual representation of what I have to do for a day."

Recall

The PCCAT enables the nurse to proceed with confidence, without the worry of forgetting a crucial lab result, the time a PRN medication (medication given when needed, not at a scheduled time) was given, the need to follow-up on a consult, or the need to discuss with the physician that the patient's nausea is not adequately controlled with the medication currently ordered. *"Yeah, I write it down if I have a question I need to ask. I have that on my checklist because there's so much going on that I might forget if I don't write it down."*

"The nurse is being constantly interrupted with phone calls, being called away. You have to stop what you're doing and go to something else and then come back…I can instantly look at my [PCCAT] and refocus and get back on track…Without [the PCCAT] you are just kind of floundering out there. It's like, have I done this?"

Most subjects indicated concern about remembering what care delivery tasks were completed, the time specific tasks were completed, and when data was charted in the permanent medical record. Another concern was that of appearing poorly prepared, foolish, or not having a response immediately available during physician rounds. Most nurses discussed reviewing the data on their PCCAT prior to calling the physician or mid-level-provider, assuring that they had the data necessary to provide the background about the patient and respond to anticipated questions.

Visual Cues

Visual cues employed in creating the PCCAT included spatial orientation, chronology, use of longitudinal data, and a personal "shorthand" for the PCCAT. Many nurses organized the information by assuring that all of the data for the patients in their care were on one sheet of paper. Spatial orientation was demonstrated by nearly all of the nurses. Generally, the PCCATs were developed with an hourly chronology. Within the chronology, intravenous (IV) medications were allocated to one section of the chronology and oral medications were recorded in a separate area; the chronology and patterns were maintained for each patient in the assignment.

Medication allergies were usually recorded in the same general area for each patient, although not necessarily in proximity to the medications.

Longitudinal data generally was limited to lab results. The lab results from the previous day were often recorded, enabling immediate evaluation when the results of the current day were recorded. If protocol orders for replacement of blood products or electrolytes were present for the patient, the nurse often included the protocol parameters in close proximity to lab results to support immediate evaluation and planning.

Several nurses used a shorthand system to serve as a reminder and/or cue regarding completed and pending actions. Cues included the use of check boxes in front of tasks, placing a check when the task was completed (see Figure 2 for an example). Another cue was placement of a 'dot' on the MAR when preparing medications for administration; the dot served as a secondary check during documentation to assure that all scheduled medications had been administered. Other nurses placed a 'strike' next to a medication when it was prepared for administration, a second 'strike' when it was given to the patient, and a final 'strike' to indicate the medication had been charted.

Color was prominent in creating and updating the PCCAT for several nurses. One color of ink would be used at the time the PCCAT was prepared, and a second color was used to make additions or add new information (see Figure xyz – trying for an additional example). In other instances, a second color was used to denote abnormal lab values. One nurse used green ink to record tasks she found she often overlooked; she believed green ink was easier for her to "see". The individual determined choice of color.

Value of Writing

Nurses suggested that transcribing data on the PCCAT supported the process of learning about a patient. The nurses expressed that they felt the process increased memory retention while also creating awareness that specific data is present and available. Some nurses believe they have a more intimate knowledge of their patients as a result of handwriting information on

the PCCAT. In addition, recording lab results (or other data) on the PCCAT stimulated thoughtfulness, supporting reflection as the nurse thought about if and how she would respond to the results.

"Writing their name down and then writing each medication or each time when I need to give [the medication]…helps me remember…the JP drain is for 705, because you'll get questions out of the blue and you have to immediately know it's for this patient. So the act of writing down things helps me remember that "[Mr. Jones] is the one with daily CBC's, not [Mr. Smith]," because I've written it down. It helps me remember."

"I think definitely when I'm sitting there in the morning doing my [PCCAT], it helps me to really think about the patient. Oh, they're on that? I didn't hear that in report because I was half asleep… You really do sit and sort of learn about what they're on and everything and if it was already printed, I think things might get overlooked, especially that early in the morning, [if not written by the nurse]."

"Every time I'm here I go through and I write everything that I need to be doing on that patient and it's just kind of like it gets in my head more and more."

"I would update everything and then I would tell [the night nurse], "This is what happened…" and then I'd be like, "See, it's right there". She would still continue [to] write and she would be like, "Oh, I like to write it." So she likes to write it down again."

DISCUSSION

This study identified the role of a cognitive artifact knowledge representation, the PCCAT (McLane, Esquivel, Turley, et al.), within the cognitive work of the RN. Data was collected through shadowing and interviewing registered nurses who provide direct patient care. Data collection was conducted on three inpatient units of a comprehensive cancer center. Findings from this study indicate that RNs create the PCCAT to provide an encompassing understanding of the clinical condition of the patient and the scheduled therapeutic and medication interventions, and to evaluate and trend diagnostic test results that are located in multiple

locations and formats. Further, the findings disclose that the PCCAT guides and supports

workflow, working memory, and cognition.

Our analysis disclosed several themes regarding the purpose and value of the PCCAT:

writing the data, information recall, information visualization, the role of visual cues, and the flow

of the day and organization. These themes are complex and interdependent. The process of

writing information on the PCCAT supports recall and working memory. Writing also enables

data configuration on PCCAT to meet personal information visualization preferences, and for

the nurse to create data relationships congruent with internal knowledge representations. Visual

cues are intimately related to visualization needs, and are supported by writing and the flexibility

to assign personal meaning to the cues. Internal knowledge representations of organization

influence information visualization and configuration, while visualization and configuration

concurrently influence organization. The product of the writing, recall, information visualization,

visual cues, and organization – the PCCAT – provides a comprehensive overview that the nurse

can use to guide the flow of the day.

The PCCAT enables patient information to be collected in one location so that the nurse

can evaluate the patient's condition and the current plan of care, and reflect upon modifications

to the plan of care that may be appropriate. As this process is repeated for each patient, the

nurse is effectively positioned to assess the 'flow of the day' and to begin to organize and

prioritize the work to be completed (C. Nemeth, et al., 2006). Absence of a succinct clinical

summary that supports the information and organization needs of the nurse would greatly

increase the time necessary for the nurse to understand the patient's condition, increase the

memory load of the nurse, and potentially compromise patient safety due to the absence of a

focused, organized, relational set of clinical data. Further, the data the nurse records on the

PCCAT is dependent upon the need of the individual for selected information.

An important facet of the cognitive work of the nurse and planning patient care is the

communication of test results, changes in the patient's condition, family or patient requests and

concerns, and nursing recommendations to members of the patient's care team. Information exchange often occurs when the recipient is ready to receive the message rather than when the nurse is prepared to communicate the message. The time of day, delays while awaiting responses to pages, surgical schedules, and similar constraints prevent immediate, and possibly convenient, dialogue. Thus the PCCAT becomes a repository of recorded data, which is available when needed to communicate information, questions, needs, and the appropriate contextual information. These notes promote confidence that the nurse 1) will not forget to communicate the data, and 2) is prepared to respond appropriately. Thus, the ability to temporarily cluster patient information for communication purposes is important to effective communication between the nurse and other care providers.

Visual cues are created representations (Card, et al., 1999) that nurses employ to direct their attention, and are indicative of tasks or cognitive work that has been completed or is pending. Visual cues such as spatial, temporal, chronology, color, or personal codes were demonstrated to be important to nurses. The meaning of these cues may be repurposed, added, or eliminated in response to the situation or changes in the nurse's cognitive processes. The nature of visual cues varied by individual, but the importance of personal cues was clearly present. Color-coding, data configuration, data proximity, longitudinal data, and chronology each played a role in directing or focusing the attention of the nurse. The lens for effective information visualization varied among the nurse subjects. The ability to personally select data, about which the nurse wishes to receive alerts, and the nature and meaning of the alert, is another key component of the PCCAT.

Several nurses expressed the belief that writing data on the PCCAT was cognitively important to their ability to recall and reflect upon the data, as well as evaluate potential implications the data may have for the patient's plan of care. The findings of this study suggest that the nurse needs to be able to manipulate or act upon data in a manner that is cognitively similar to writing data, and that supports the retention and recall relative to handwriting.

The themes identified during data analysis can be aligned with the model in Figure 1. Information visualization and visual cues are guided by the internal knowledge representations needs and preferences of the nurse. Information visualization and visual cues are often a part of the design of external knowledge representations the nurse accesses for data, but the meaning for the nurse is influenced by his/her internal knowledge representations. Organization and flow of the day are a derivative of internal knowledge representation in response to data present on the PCCAT. Working memory support, or recall, is the result of interaction between the PCCAT and internal knowledge representations. The importance of writing data on the PCCAT evidenced interaction with working memory and internal knowledge representations.

The sample size and specialized clinical focus of the study site limit the ability to generalize the outcomes to other sites. Sample size was not sufficient to support correlation of data with years of nursing experience. The environment of transition from paper to electronic medical records and documentation at the study site may have influenced the role of the PCCAT, and the outcomes may differ in environments with all paper or fully electronic medical records.

CONCLUSION

The nursing process – assessment, evaluation, development of plan of care, and the implementation and evaluation of the care plan – are central to the why nurses create the PCCAT. This study has established that the PCCAT is an important cognitive work tool for nurses, supporting working memory, providing a medium of information visualization, enabling work organization and prioritization, and directly and indirectly supporting perception, learning, and reasoning.

The process of creating an automated PCCAT is a much more complex undertaking than has been assumed. A greater understanding of nurse cognition, particularly as cognition relates to external knowledge representations, may indicate the need for a technology solution which supports much greater flexibility and user manipulation to support customization of the PCCAT (Nancy M Lorenzi, 2004; Nancy M. Lorenzi & Riley, 2000). The need of the nurse to select,

configure, and annotate clinical data, with consideration for the practice environment, may make automated PCCATs a more distant goal.

The influence of organizational culture on the data nurses desire or need to include in their clinical summaries also warrants exploration. Finally, the influence of years of nursing experience on the content, detail, configuration, and use of cognitive artifacts similar to the PCCAT may provide important insight regarding the importance of cognitive artifacts and to the import of cognitive artifacts on the nursing process. It is recommended that future studies explore the possible link between handwriting and cognition, and the consequences that may be related to replacement of hand written artifacts with electronic summaries.

Acknowledgements

Summary points

What was known before the study

- Nurses prepare a document that they use during the process of patient care delivery
- This document has not been studied in the context of care delivery focusing on nurse cognition

What is known after the study

- The document nurses prepare is a personally created cognitive artifact (PCCAT)
- Nurses need to customize PCCAT content based upon personal need for patient information in order configure data in a meaningful way, assess the flow of the day, assist with organization, establish visual cues, and support recall
- Nurses need to create temporarily clusters of patient information that can be accessed for a variety of purposes including communication with other providers, reminders to document
- Nurses need to create and embed personal cues in the PCCAT that focus attention and guide organization and prioritization
- PCCAT documents are important to the cognitive work of the nurse

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PROJECT SUMMARY & FUTURE DIRECTION

The three manuscripts presented as part of this dissertation represent an initial step in understanding the importance and role of knowledge representations and structures, as exemplified by the PCCAT, to the cognitive work of the nurse. We began with the concept analysis process, which identified and delimited the attributes of PCCAT-like cognitive artifacts. The concept analysis should assist future researchers as an objective measure to determine if the knowledge representations they are studying are a cognitive artifact, and if they are PCCAT derivatives.

The second manuscript describes the layers of data, understanding, and insight that were attained with the use of a multi-method approach to data collection. A less complex approach would have left important information undiscovered. The qualitative research process of iterative analysis, in combination with document analysis and coding, shadowing, interviewing, and a clinical scenario created a rich canvas that permitted the data to be examined from multiple perspectives.

Our third manuscript describes and discusses our analysis and understanding of the data. This paper provides an initial understanding of the complexity of nursing practice, and the importance of flexible, immediately available knowledge artifacts to the work of the nurse. We discovered that much of the utility of the PCCAT is embedded in the configuration created by the individual nurse as the data is recorded. The personalized information visualization design is further augmented by the ability to create visual cues that hold personal meaning for recall or other purposes. Further, the nurse needs to be able to record notes that serve as personal reminders with various intents. These are examples of the complexity of the PCCAT and it's relationship to the cognitive work of the nurse

The work completed to date serves as a framework to guide future avenues of study. The objective of this research study was to identify and define the requirements and other criteria necessary for an information technology solution to the PCCAT, and assumed that

research would provide clear direction to the definition of those elements. We discovered that the role of the PCCAT in the cognitive work of the nurse has dimensions of complexity not anticipated prior to the study, and opens the door to several research domains that may add greater understanding of the requirements of an information system alternative to the PCCAT.

Not surprisingly, nurses need to be able to define the data they require in the context of the condition of the patient and nursing care standards. Further study and exploration is required to identify the influence of nursing unit culture, and expectations of the clinical service, on the data nurses select to record on the PCCAT. Another topic for future exploration is the reflection and reflexivity associated with choosing the data to be recorded on this knowledge representation, and how the process of selecting data may influence the cognitive work of the nurse. While we believe that the ability to retrieve and manipulate data entry on the PCCAT serves at least two purposes – aiding the recall process, and facilitating reflection and care planning – this insight requires additional study and validation.

A construct identified through this work is the importance of a comprehensive overview of the nurse's patient care assignment and the care those patients would require over the next eight to twelve hours. The paper PCCAT enables visualization of the care needs of each patient within the context of the other patients in a nurse's assignment. This perspective enables the nurse to establish priorities for each patient in the context of the needs of all of the patients included in the assignment, organize care activities, and prioritize care delivery. We do not know if subset of the data recorded on the PCCAT have a greater influence on development of a mental vision of the work and priorities for the shift, and this question is a consideration for future study.

Clinical experience may influence the data nurses record on the PCCAT, as well as how nurses use the PCCAT. Our study sample was too small to measure this outcome, but there were subtle indications that a difference may exist. Additional study is needed to explore the influence of clinical experience, as well as experience within a clinical specialty. While mindful

that the PCCAT is an example of knowledge representation and knowledge structure, the data a nurse records on the PCCAT may suggest his or her understanding of the patient's disease process and the potential complications and side effects the patient may experience in response to the disease and treatment program. Shoulwe d this line of reasoning be supported by future study, it may have potential application to the orientation and mentoring process of novice nurses.

The need to personally write data on the PCCAT was articulated by several nurses in the study. These nurses believed that the psychomotor action of writing the data assisted their later recall, as well as assuring the nurse that the data was present and its location on the PCCAT. An additional dimension the nurses described was the personal reflection about the plan of care that was associated with writing the data. A better understanding of this phenomenon and the requirements and benefits of writing the clinical data is an additional avenue of study and may contribution to the development of an information systems generated PCCAT alternative.

We developed a robust PCCAT taxonomy, accompanied by a comprehensive appreciation of the scope and complexity of the data nurses require to support patient care decisions. The next step in the development of the taxonomy is to mapping to a nursing terminology system, creating a foundation for future study. Completion of the PCCAT ontology is an additional focus. Data collected from the eight clinical scenarios remains to be analyzed. Completion of this data analysis will strengthen and clarify the insights and conclusions identified from the earlier stages, providing a more integrated understanding of the PCCAT knowledge representation.

The work described in the three manuscripts is part of a larger body of research regarding cognitive work, knowledge representations, and information technology as they relate to nursing practice. The agenda for future research of knowledge structures and representations like the PCCAT is multifaceted. The research topics we have just described will contribute to the

framework of requirements necessary for development of an information systems solution to the PCCAT.

The conclusions reported here cannot be generalized due to the sample size and the specialized clinical nature of the study site. Replication in a general acute-care medical-surgical environment is warranted to learn if the conclusions developed during this study are unique the oncology. Study replication in an acute-care environment with a fully implemented EMR and in an environment that has not begun implementation of an EMR would also be helpful in creating understanding about knowledge representations and knowledge structures of nurses, and the influence of those representations on the cognitive work of the nurse.

When we developed and initiated study of the PCCAT, we had a vision that included1) identification and definition of the data that nurses record, 2) identification of the heuristics nurses use when selecting data to be recorded, 3) understand how the PCCAT supports the recall and working memory of nurses, and 4) understand the purpose of the PCCAT and how it supports nursing practice. We designed a study that would allow us to realize the vision and achieve the desired aims. In the final analysis, we achieve the aims while finding the vision has a different shape and hue than the vision we expected to touch.

We have learned that the knowledge representations that nurses create and use in to support their practice are much more complex, and much more integral to practice, than originally envisioned. The PCCAT is a unique workspace in which the data the nurse finds important to the care of the patient is woven with their knowledge of the patient and the cares needs of the patient. To this workspace is added the reflection, reflexivity, and decision-making of the nurse that ultimately drives patient care delivery. Now that we have a foundational understanding of elements of this workspace, we are prepared to continue to envision what it may look like with the addition of information technology.

The cognitive work of the nurse and the relationship between the nurse and his or her knowledge representation begins with structuring the document. The nurse will be able to select

and arrange the external data about the patient. This information technology application version of our knowledge representation needs to support selection and movement of data in ways that are meaningful to the individual. Historical information, such as recent lab values, need to be displayed in tabular or graphic form based upon the preference of the user. Upper and lower limit ranges should be readily available when desired, as well as 'panic-value' ranges. Color has meaning to some nurses, and the ability to apply a color of choice is important. The cognitive processes associated with selection, arrangement, choosing data from past events, and creating color-coded schemata will promote reflection and thoughtfulness similar to handwriting.

Understanding that individuals vary with regard to data configurations that meaningful and that support cognition, the information system solution to the PCCAT will allow the nurse to configure the data in a manner that is aligned with his or her needs for information visualization. The nurse will to be able to experiment with various configurations to find the visualization patterns that resonate, and to be able to change those patterns as the nurse's internal knowledge representations change through experience and new understandings.

Another information visualization feature of our electronic PCCAT will allow the nurse to add personal cues in locations, colors, and patterns that are meaningful to the individual. Perhaps a nurse prefers the potassium-wasting medications to be in close proximity to the potassium lab values. Another nurse may configure neurologic vital signs and ICP values in immediate proximity. Often integral to recall processes, visual cues are dynamic, changing as the shift progresses and tasks are added, completed, or initiated. Within the format of visual cues is the ability to add notes, not intended for use by others, and generally created to support recall from various perspectives (documentation, reminder to follow-up, communication content) purpose each of which is to support recall in some capacity. Visual cues and personal notes, elements of information visualization, are also constructs of writing.

Tomorrow's electronic PCCAT will enable visualization from several perspectives. The care needs of an individual patient, including all scheduled medications, can be viewed by hour,

blocks of time, and for the entire shift. PRN medications can be viewed on demand, including the last time of administration and the result of the intervention. Another view will support visualization of scheduled care for all assigned patients in user defined time blocks. Personal notes or visual cues can also be visualized in the comprehensive assignment view, which further supports prioritization of functions.

Our information technology solution will be integrated with the clinical information systems present in the organization, and support biofeedback security that seamlessly protects PHI of the patient and the nurse. The application will support a two-way interface as appropriate, permitting transmission of appropriate documentation as directed by the nurse. Our electronic PCCAT will be supported on a hand-held form factor that is lightweight and slips into the pocket of a lab coat or warm-up scrub jacket. Rather than scrolling, users should be able to circumscribe and 'zoom in', and 'zoom out' with a single 'click'.

The description above is a vision, and today's technology has not matured to support realization of this vision. Earlier in this summary we described research programs that must be implemented while technology continues to become able to help this vision become reality. The work of this study has provided previously unknown information about the requirements of an information system solution to the knowledge representation that we call the PCCAT. The domains of study – information visualization, data selection and configuration, working memory support, and microcosm and macrocosm views patient needs and work – have been establish. It remains for this research agenda to commence. In summary, this study has envisioned the agenda, established the direction, and described the outcome.