

# **How Cognitive Artifact Support of Acute Care Distributed Cognition Affects Patient Safety**

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## **Abstract**

Demands for acute care are uncertain and change frequently, while resources to meet them are constrained and subject to production pressure. To manage this conflict, the anesthesiology coordinator makes continual assessments and tradeoffs between and among patients and work groups. The complexity and uncertainty of the acute environment requires the creation and use of common artifacts such as display boards, lists, and worksheets that are part of the distributed cognition. We describe a project in which ethnographic methods reveal the strategies, shown in schemata analyses, that anesthesia coordinators use to develop schedules. Such research promises to benefit the evolution of medical informatics, which is the software and computing systems that support the organization, management and use of health care information. Experience shows that digital replicas of physical cognitive artifacts are often blind to the needs of those who are expected to use them. The resulting effects of this clumsy automation can impede staff performance rather than improve it. The research approach described here will assist in understanding the traits of acute care technical work and successful physical artifacts, which promises to improve medical informatics. Better digital cognitive artifacts will benefit work processes, including planning, communications and resource management and thereby benefit patient safety.

## **1 Acute Care**

Much of the cognitive activity in complex, high hazard, high tempo work settings such as air traffic control, military operations, and acute health care is directed toward anticipation of future requirements, deadlock prediction, reaction to evolving situations, and resource reallocation. These complex cognitive activities are difficult to study because they involve deep domain knowledge. They also require a detailed

understanding of the myriad local details and contingencies that offer opportunities for action and limit those opportunities.

Acute health care organizations include tightly constrained teams of service providers who perform complex procedures that routinely have significant consequences. The conduct of a single anaesthetic and surgery requires synchronized and coordinated effort from every department that is involved. The 24 OR's at the author's research site handle roughly 50 to 80 surgical and pain management cases every day. The process of planning and management for the inpatient operating room unit (IOR) and outpatient clinic (SurgiCenter) are far more complex than most outsiders appreciate. Care providers and support staff all have to appraise the published schedule, distribute resources, coordinate their efforts with those of other personnel and reassess their situation and plans in frequent cycles through the day. Complex planning and management activities such as these are part of what Barley and Orr [1] and Cook, Woods, Miller [2] describe as "technical work."

Intentions and changes to anesthesia assignments involve deliberate assessments and tradeoffs *among* and *between* patients and work groups. This planning and management activity occurs at the level of the unit, not the individual patient. The scale, level of complexity, and the density of knowledge that comprises the sharp end of practice makes the study of team cognition a particular challenge.

## **2 Cognitive Artifact**

People actively manage the dynamic characteristics of their work place by drawing on a deep knowledge of their work domain to create and use artifacts. [3] Cognitive artifacts [4] are physical objects that acute care team members create and use in order to manage information in their work environment.

Artifacts are used to encode information about a domain in order to capture it, to use it, and to convey it a compact, efficient manner. This is because information involved in anesthesia assignment coordination is too complex to be portrayed in its entirety. Practitioners create and continuously use cognitive artifacts such as schedules and status boards in order to manage crucial knowledge regarding the unit work flow. This makes their team's cognitive activities more robust. In fact, anesthesia assignment coordination is so complex that it would be impossible to perform without such artifacts.

The content of acute care cognitive artifacts is inherently connected to what is meaningful in this work domain. If the artifacts were not valuable to practitioners they would not exist, as there is no time available for anything other than essentials. This makes them a valuable resource to understand acute care team cognition.

## **3 Cognition Research**

The study of artifacts reveals how cognitive activities are accomplished and also shows their strengths and vulnerabilities. Nemeth [5] describes how studying these artifacts reveals the deep knowledge acute care team members used to create them.

Looking and listening alone are not enough to grasp the density and complexity of information and interaction in surgical and critical care. We need research

methods such as those shown in Figure 1 to identify and analyze aspects of this complex environment that are not readily apparent. Artifact analysis provides such a research method. Phase One in Figure 1 shows how the author organized research activity to understand acute care cognition at the unit level. Phases Two and Three suggest how Phase One findings will be applied to perform further work in this area.

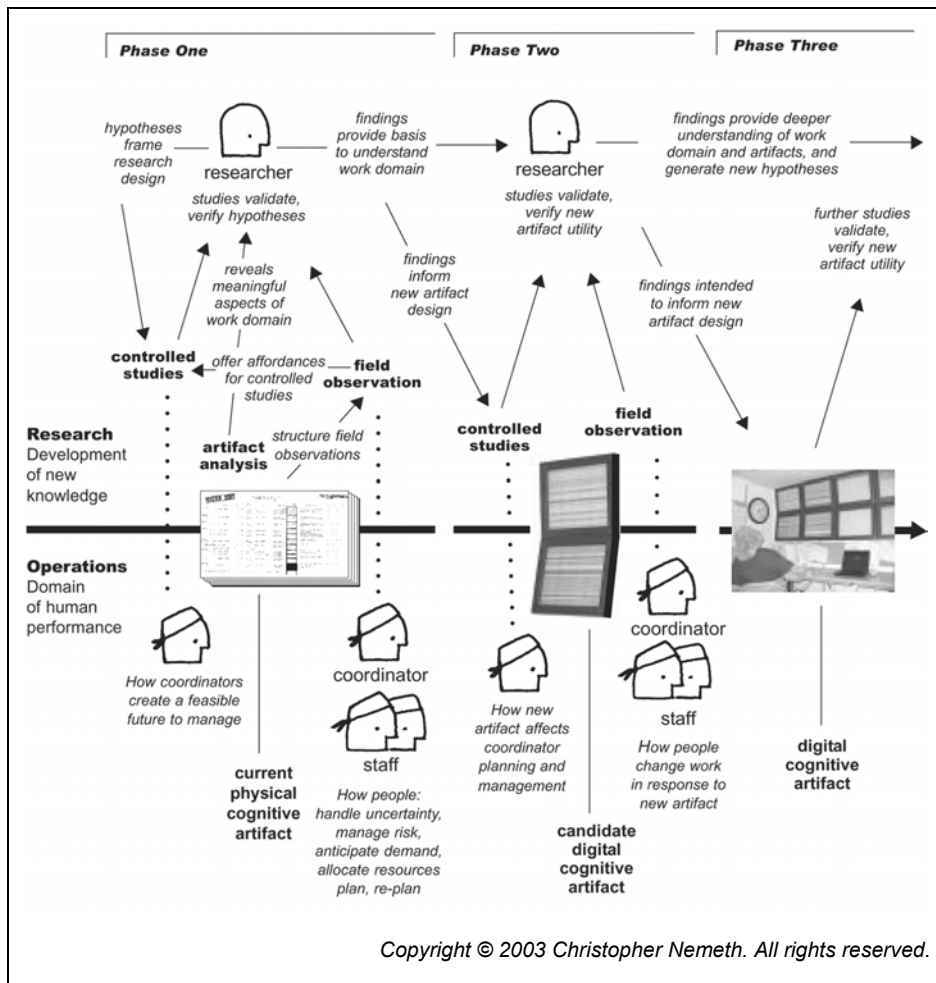


Figure 1: Three Research Phases in Medical Informatics

Artifacts reveal information about two research themes in acute care cognition. The first theme is the effort to understand the acute care work domain as a complex, high hazard, time-pressured, interrupt-driven environment. The second theme is the effort to understand how team members manage the domain using strategies such as anticipation, hedging and husbanding resources and making trade-offs.

In Phase One, this study used artifacts to study cognition at the unit level in two directions. One path shows how the master schedule artifact is created. The second path shows how the master schedule is used to reveal the basis for its creation.

### 3.1 Describing Schedule Creation

Research activity in phase one first studied how anesthesia coordinators create the daily schedule for the IOR and SurgiCenter and then manage events the following day. The investigator invited coordinators to write a schedule while being recorded on videotape. Four coordinators out of eight were available and agreed to participate. Three coordinators were willing to be videotaped and their session. Analyses of their sessions revealed how the coordinators allocated resources to meet demand in the interest of influencing how activity should occur the following day. As Figure 2

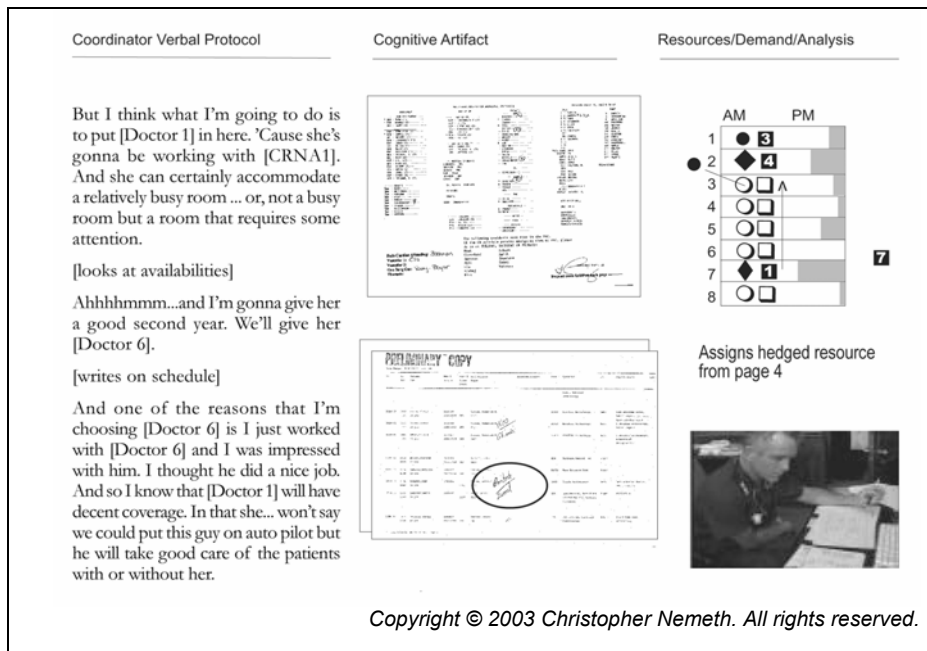


Figure 2. Coordinator Cognition Analyses

shows, analyses included a session transcript (at left), artifact analysis (at center) and diagrams (at right) that show each step in the process of resource assignment. Transcripts of anesthesia coordinator verbal description while writing the schedule indicated how each goes about schedule development. Review of the marks made on the daily availability (staff schedule) sheet and the preliminary master schedule showed how coordinators use these cognitive artifacts to develop a final master

schedule. Summaries of the analyses revealed different strategies that coordinators employ in the way they allocate resources.

### **3.2 Describing Acute Care**

The second path in Phase One reverses the procedure by studying the acute care team in order to understand how they use cognitive artifacts to manage their daily activity. By starting with the master schedule, the researcher used it as an encoded representation that describes the nature of this complex work domain. He captured subject comments and events as they occurred by writing field notes of daily activity into two pocket-size booklets. He conducted informal interviews with roughly 25 nurses and coordinators and 40 anaesthesiologists and certified registered nurse anaesthesiologists (CRNA's) and anesthesia coordinators while making observations. He reviewed the structure and variations of roughly fifteen daily availabilities, master schedules and OR Graphs over three months. During this time the author wrote twelve case studies to synthesize the observations, comments from informal interviews and analysis. Each case study followed a similar structure: title, brief summary, background, sequence, and comment. The sequence section of the case study included actual behaviour and quotations that occurred during observations. These data form the foundation on which conclusions about acute care cognition are based. The author "unpacked" the meaning that was embedded in observed behaviour in the case study comment section.

## **4 Findings**

Phase One research revealed information about cognitive activity among coordinators and among acute care team members that had long been suspected yet never accounted for. The cognitive activity demonstrated by both groups shows that the complexity of their cognition and interaction matches that of their environment. [6] Coordinators, for instance, achieve and maintain the balance between demand and resource by employing a range of strategies. They predict resource availability, build consensus, plan, assess, verify, redirect, set norms, re-plan, resolve disputes, speculate, anticipate, stash and husband resources, and bump procedures to make way for emergencies.

Coordinator expertise in writing the master schedule exerts a strong influence on the way that the schedule plays out the following day. This expertise rests on three abilities: awareness of requirements and resources, grasp of how needs and resources are likely to change, and facility with adjusting and re-planning resources. Schedule design flows from the sensibility and values that the coordinator uses to make decisions. To a greater or lesser degree, each of the coordinators is thorough, accurate, fair, sensitive and opportunistic. Each coordinator, though, demonstrates the use of these traits differently. While one coordinator develops the schedule to make her day as easy as possible for herself, another tries to optimize the learning experience for residents, while yet another tries to be as fair as possible for everyone on the unit. Regardless of the strategy, each schedule succeeds. This makes it possible to manage a daily schedule of activity that would be impossible to manage without it.

## 5 Conclusions

If erroneous action is due to human-system mismatch, the anesthesia coordinator's work has a direct bearing on minimizing it. The message that has for those of us who study "error" is that deep knowledge of technical work makes it possible to anticipate, to prepare for, and to even craft the future. Understanding and supporting that activity is a strong step toward the achievement of robust performance.

Successful design depends on understanding the ordinary work practices, tasks and situational requirements of users. [7] However, few information technology projects invest the necessary attention to this understand the work domain or the cognitive artifacts that represent it. For this reason, obstacles to the use of computers in health care have not been computers but rather understanding the complex health care systems in which such machines exist. The study of artifacts not only reveals the deep structure of acute care cognition. It also demonstrates the physical traits of cognitive artifacts that are often overlooked. These traits provide a foundation for the development of useful digital artifacts. They also point the way that information technology can effectively support practitioner cognitive activity.

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