Human Factors and Ergonomics Society
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Symposium:

Insights from Technical Work Studies in Healthcare

Chair & Organizer: Richard Cook, University of Chicago
Co-Chair: David Woods, The Ohio State University

Studies of technical work in healthcare offer prospects for developing deep understanding of the conflicts, demands, hazards, and opportunities that shape healthcare work. Efforts to produce this deep understanding are underway at several centers and employ a variety of methods including ethnographic research, studies of cognitive artifacts, and video recording and analysis. In each case, the research work results from intimate, sustained collaborations between experts in human performance and experts in clinical work. The collected results of these studies offer powerful insight into technical work and technical workers. They provide a set of bench-marks: carefully calibrated, densely packed, methodologically sound characterizations of the technical work of healthcare. Such benchmarks are essential for planning, conducting, and interpreting the results of experimental interventions directed at safety. This symposium presents the early results of these inquiries into the complexity of technical work in healthcare.

An introduction and five presentations on current research activity:

CTL Cognitive Technologies Laboratory

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HOW COGNITIVE ARTIFACTS SUPPORT DISTRIBUTED COGNITION IN ACUTE CARE

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In acute health care, tightly constrained teams of service providers perform complex procedures that routinely have significant consequences. Recent patient safety research encourages the use of decision support tools to improve human performance. Multiple hospital departments collaborate in a distributed cognition to balance the demand for health care with resources such as care providers, equipment and facilities. To plan and manage the balance, an anesthesiologist and a nurse coordinator predict resource availability, build consensus among team members, resolve disputes, plan resource allocation, assess and re-plan the balance between need and resources, speculate about future needs, create trial solutions, anticipate resource requirements, bump procedures and stash and husband resources. The Availabilities Sheet, Master Schedule, Operating Room (OR) Graph and OR Board are four cognitive artifacts used to support their work. Artifacts must, at a minimum, be reliable, informative, efficient, clear, accurate, and malleable. Improvements to these and other information tools will benefit team work processes and thereby enhance patient safety. An example demonstrates how cognitive artifacts are used to support distributed cognition.

Acute and outpatient health care organizations are comprised of tightly constrained teams of service providers who perform complex procedures that routinely have significant consequences. Like nuclear power generation, the military and aviation, health care is a high hazard application with extraordinary implications for the well being of its workers and clients. Studies of patient safety have identified gaps in current patient safety research including what Cooper (2000: 5, 69) describes as the need for "different research methodologies... research about communication and information-sharing among health care providers... studies of work loads...and human factors."

Recent research into patient safety issues "strongly supports the use of decision support tools to improve human performance." To improve work processes, those tools must reflect a detailed understanding of both the strengths and the weak points of current sharp end (operator) knowledge. (Cook, Woods, and Miller, 1998). Klein (2000), Cook and Woods (1996), and Xiao, et. al. (2001), have previously addressed cognitive issues in health care work. This paper, which summarizes some of the key themes in Nemeth (2003), describes the use of cognitive artifacts in health care, and considers implications for patient safety.

Methods

Research on anesthesia patient safety typically focuses on device design and uses the individual case as the unit of analysis. However, the conflicts among production pressure, resource availability, demand, and the complexity of anesthetic and surgical care are resolved *across* and *between* cases. Unit-level study, then, requires methods from more than one discipline because "different hazard sources require different control strategies, it becomes clear that we have to study *the vertical interaction among the decision makers*." (emphasis in original) (Rasmussen, 1997: 67-70)

To that end, this research has employed methods from both sociology and human factors. Sociological methods include workplace studies (Luff, Hindmarsh and Heath 2000), conversational analysis (Drew and Heritage 1992), interaction analysis (Frolich, 1993), and informal interviews. Human factors methods include observation and analysis (Nemeth, *in press*) as well as artifact analysis. Case studies and cognitive activity summaries (Hollnagel, 1988: 263-7) describe the nature and implications of those activities.

Distributed Cognition

Distributed cognition is commonly shared knowledge that benefits a group but cannot be known by any single individual (Hutchins, 1995). Through socially distributed cognition (Perry, 1999), individuals cultivatea mutual awareness and an understanding that is timely, thorough and accurate in order to collectively accomplish shared goals. In health care, this cognition is distributed across the sharp (operator) end and the blunt (support) end. In daily procedures scheduling, it spans members of multiple departments including, but not limited to, Anesthesia and Critical Care (DACC), Surgery, Nuclear Medicine, Gastrointestinal Endoscopy, Interventional Radiology, Diagnostic Radiology, and Psychiatry.

Coordination of this complex, variable activity is necessary because operating rooms are a tightly coupled (Perrow, 1999) environment. The effect of changes are difficult to predict, particularly by those who are not skilled in OR management. Coordination incorporates deliberate assessments and tradeoffs between and among patients and work groups "to reduce variability and independent behavior in order to enhance credibility." (Anesthesiologist T. Cutter, Personal Communication, February, 2002). An anesthesia coordinator and a nurse coordinator plan and execute a daily schedule in order to balance the demand for health care with resources such as care providers, equipment, facilities. Through the day, anesthesia and nursing assignments are changed frequently and rapidly as coordinators work to reconcile moment-by-moment shifts in resources and demands. To achieve and maintain this balance, coordinators:

Predict resource availability—Assess actual versus nominal resource availability

Build consensus— Develop expectations about and support for future arrangements

Plan—Commit resources to satisfy needs. Achieve balance that will satisfy requirements at multiple levels

Assess—Evaluate how well the current plan satisfies requirements

Re-plan—Revise assignments in response to, or in anticipation of, imbalances

Resolve disputes—Diffuse conflict when resource and demand become unbalanced

Speculate—Estimate the nature and likelihood of conditions in the near future

Create trial solutions— Simulate possible arrangements for others to consider

Bump procedures—Designate a room on regular rotation in which a routine procedure will be postponed so that an emergency can be accommodated

Anticipate—Foresee potential requirements for scarce resources. Use available staff to satisfy unique or dedicated requirements. Send for staff and equipment ahead of need.

Stash resources—Send staff members on temporary assignment such as a break or lunch to return within a predictable time

Husband resources—Adjust availability of staff through lab day assignments

Cognitive Artifacts

The complexity and uncertainty of the Inpatient Operating Room (IOR) environment requires the creation and use of cognitive artifacts (Hutchins, 2001 and Norman, 1992, 1993), which are information tools that are part of the distributed cognition. In the IOR and intensive care unit (ICU), cognitive artifacts include such common items as display boards, lists, and worksheets that are used in a variety of ways. A month in advance of the day procedures will be performed, block time and staff schedules are used to anticipate the balance between staff the type and number of procedures. Four artifacts support distributed cognition in the IOR. Three of them are hard copy printouts and the fourth is a dry marker board with moveable magnetic plaques.

Availabilities Sheet—Constrains and qualifies the supply of health care providers.

Master Schedule—Provides a means to allocate and trade-off resources, to invite others to develop a consensus regarding the future, to indicate the current status, to serve as a platform for decision-making, and to account for what actually occurred.

OR Graph—Confirms accomplished tasks for the purpose of billing.

OR Board—Serves as a dynamic interactive platform to negotiate, make trade-offs and decisions, and to speculate about the future. The board can be reconfigured, allowing staff to be relocated, stashed, held in suspense, or reassigned. As a social artifact, it is shared and may be updated by any attending anesthesiologist, resident or nurse anesthetist (CRNA). Only information on present and future status is displayed. Figure One portrays the flow of information through these artifacts from initial planning through managing the day of procedures and accounting for the procedures that were actually performed.

Figure One

Content Maps From Artifact to Artifact

Cognitive artifacts include all knowledge that is relevant to the collective awareness of acute care team members regarding plans, current activity and accomplished work. Content transfers, or "maps," from earlier to later artifacts in deliberate and controlled ways. As time progresses, information becomes more specific. Constraints are expressed at each stage. This approach to resource allocation optimizes demand satisfaction and resource use.

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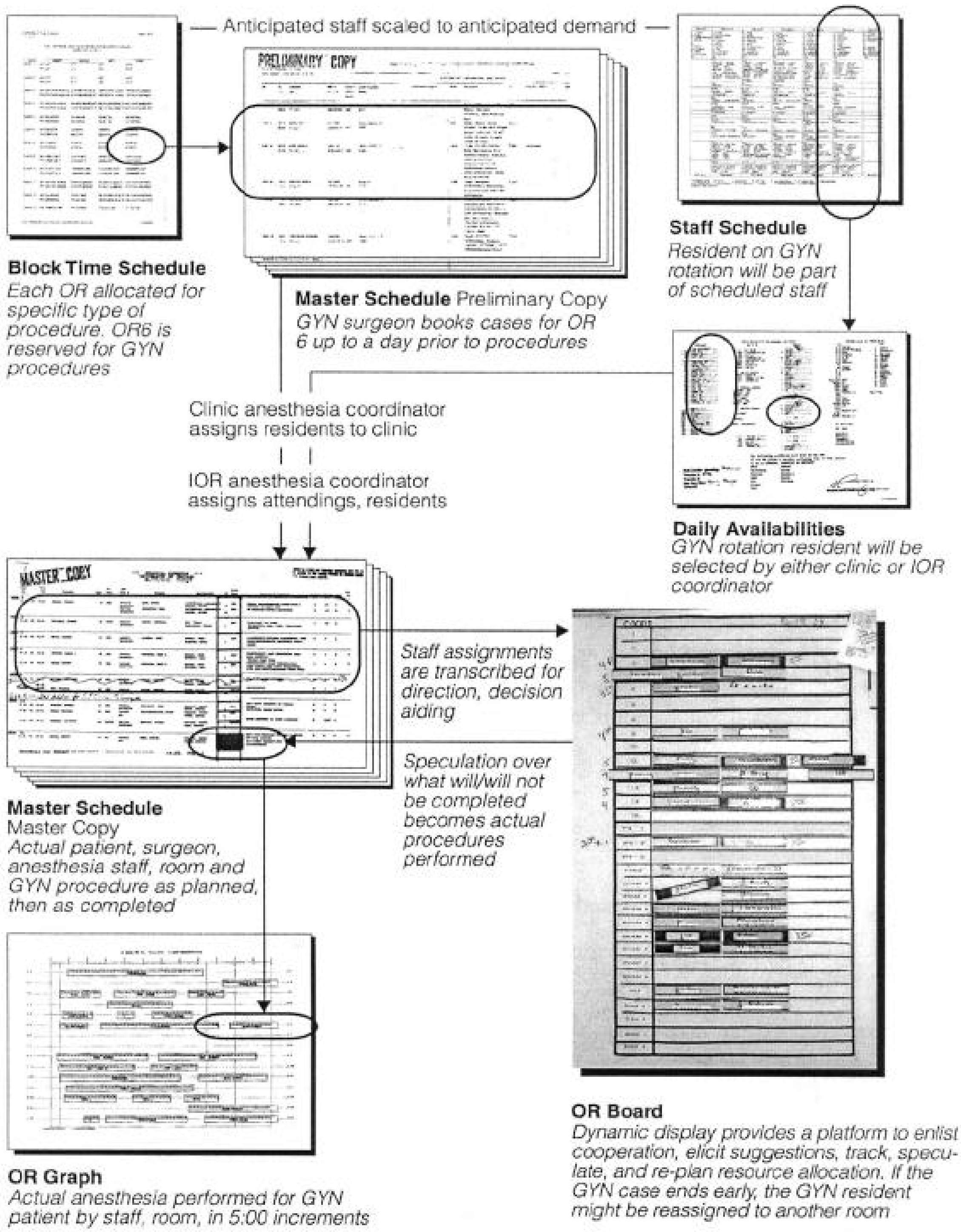

To support distributed cognition, these artifacts must at least be:

Reliable—Available for use when needed

Informative—Contain information that pertains to circumstances

Efficient—Impose the least effort necessary to obtain information.

Clear—Unambiguous and free from confusion.

Accurate—Reflect circumstances free from error

Malleable—Able to be manipulated by those who use them

Example: Soft Emergency

The following example shows how the anesthesia coordinator uses the master schedule to distribute cognition. Here, the Anesthesia Coordinator (AC) in the operating room (OR) takes a call from a surgeon who is declaring a case as an emergency. Over ten minutes, the emergency threatened to invoke a predetermined arrangement to "bump" an elective procedure out of the way in order to clear an operating room for a higher priority procedure. While the bump arrangement works, the staff prefers not to use it if possible because bumping causes significant changes to the way that staff, rooms, equipment and patients are assigned.

The sequence of events occurs from about 1130 to 1140. Portions of the dialog that occur at the Coordinator station provide a sense of what is occurring.

AC (on phone) *I don't think we can do it today. We can book it and see if we can fit it in.*

AC (on phone) *You're in the bump room, Number 1.*

AC (on phone) *He wants to do it*

AC: (on phone) *I don't make those decisions Why am I being bumped? Is this really an emergency?*

AC *You'll have to talk to him.*

CRNA *Are we being bumped?*

AC *Yes, you're being bumped.*

CRNA *How do they decide which rooms get bumped?*

AC *The bump list.*

CRNA *Doesn't it make sense to bump by the severity of the case?*

AC: *It depends on the surgeons to make those decisions.*

AC: (to nurse coordinator) *Clean it up and let's set it up.*

AC *Ask the person bumping to talk to the surgeon who is being bumped.*

NC *Six is coming out.*

AC: (to nurse coordinator) *We can put [Surgeon 1] in there. (Calls, no answer.)*

(to nurse coordinator) *We can put [Surgeon 2] in 4 and [Surgeon 1] in 6. Let me page [Surgeon 1].*
(to nurse coordinator) *You're planning to put something in 6.*

(points to a case on the add-on list)
(pages [Surgeon 2])(calls [Surgeon 2])

Nurse (while walking past station) *Are we being bumped? Is this for sure now?*

AC (to nurse) *Do the scheduled case*

AC (to [Surgeon 1]) [Surgeon 1], *Room 6 is coming out.*

(to [Surgeon 2]) [Surgeon 2], [AC]. *I just talked to [Surgeon 1] and he doesn't mind waiting 45 minutes.*

* * *

AC *When they declare emergency I don't have anything to do with it. We let them work it out.*

AC *I struck a deal by getting [Surgeon 1] to wait 45 minutes and was able to put him into a room that was coming open. That avoided having to bump a procedure*

Within ten minutes, the coordinator had fielded a potential problem, put others on a course to create solutions, found a feasible alternative, presented it to both surgeons, elicited their support and avoided bumping a procedure. The AC averted a confrontation and made use of available resources through deft diplomacy, a deep understanding of the environment, use of cognitive artifacts and participation in the team's distributed cognition. To do this, the AC had to know a great deal about how this environment works in the present and might work in the near future. Without this knowledge, the system would continue to work but certainly not as gracefully.

Conclusion

This research describes the management of complex surgical unit technical work processes and the cognitive artifacts that are used to support them. Additional work in this area depicts the actual nature of health care team interaction. Future work will seek to identify the patterns and character of health care team work processes with regard to planning and decision making and to determine their effect on resource allocation. This is in the interest of proposing and evaluating the effect of new approaches to the use of information and informatics in this complex high-risk environment.

Better information tools will benefit team work processes, including planning, communications and resource management. By extension, such improvements will also enhance patient safety.

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References

Berg, M. (1997). *Rationalizing Medical Work.* Cambridge, MA: The MIT Press.

Cook, R. and Woods, D. (1996). Adapting to New Technology in the Operating Room, *Human Factors*, 38,4, 593-613.

Cook, R., Woods, D. and Miller, C. (1998). *A Tale of Two Stories: Contrasting Views of Patient Safety*. Chicago: National Health Care Safety Council of the National Patient Safety Foundation, American Medical Association.

Cooper, J.B. (2000). *Current Research on Patient Safety in the United States*. Chicago: National Patient Safety Foundation.

Drew, P. and Heritage, J. (Eds.). (1992). *Talk at Work.* New York: Cambridge University Press.

Frolich, D.M. (1993). Adding Interaction Analysis to the User Research Portfolio, Workshop on Rethinking Theoretical Frameworks for Human Computer Interaction at *InterCHI '93.* Amsterdam: Association for Computing Machinery.

Gentner, D.G., and Stevens, A.L. (1983). *Mental Models*. Hillsdale, NJ: Lawence Erlbaum.

Heath, C. and Luff, P. (2000). *Technology in Action.* New York: Cambridge University Press.

Hollnagel, E. (1988). Mental Models and Model Mentality. In Goodstein, L.P., Andersen, H.B., and Olsen, S.E. (Eds.). Tasks, Errors and Mental Models. (pp.261-8) New York: Taylor and Francis.

Hutchins, E. (2002). Cognitive Artifacts. Retrieved on July 7, 2002 from the MIT COGNET Web Site: http://cognet.mit.edu/MITECS/Entry/ hutchins.

Klein, G. (2000). *Sources of Power.* Cambridge, MA: The MIT Press.

Luff, P., Hindmarsh, J. and Heath, C. (Eds.). (2000). *Workplace Studies: Recovering Work Practice and Informing System Design*. New York: Cambridge University Press.

Nemeth, C. *(in press). Human Factors Methods for Design.* London: Taylor & Francis.

Nemeth, C. (2003). *The Master Schedule: How Cognitive Artifacts Affect Acute Care Distributed Cognition.* Doctoral Thesis. Cincinnati, OH: The Union Institute and University.

Norman, D. (1993). *Things That Make Us Smart.* New York: Addison Wesley.

Norman, D. (1992). *Turn Signals Are the Facial Expressions of Automobiles.* New York: Addison Wesley.

Perrow, C. (1999). *Normal Accidents*. Princeton, NJ: Princeton University Press.

Rasmussen, J. (1997). Merging Paradigms: Decision Making, Management, and Cognitive Control. In Flin, R, Salas, E., Strub, M., and Martin, L. (Eds.). *Decision Making Under Stress*. (pp. 67-81). Aldershot, UK: Ashgate.

Xiao, Y., Lasome, C., Moss, J., Mackenzie, C.F., and Farsi, S. (2001, September). Cognitive Properties of a Whiteboard. In Prinz, W., Jarke, M., Rogers, Y., Schmidt, K., and Wulf, V. (Eds). *Proceedings of the Seventh European Conference on Computer-Supported Cooperative Work.* Bonn: Kluwer Academic Publishers.