# Crafting Information Technology Solutions, Not Experiments, for the Emergency Department

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 concerned with the anticipation of future requirements, prediction of deadlocks, reaction to evolving situations, and reallocation of resources. 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 and limit opportunities for action. This has particular import for the emergency department (ED) as one of the most complex, uncertain, and variable settings in health care. Many EDs are under increasing pressure to accommodate patients for longer periods and to perform more complex therapeutic and diagnostic interventions in order to compensate for resource limitations elsewhere in the facility.[1,2] This imposes new demands on ED team members to coordinate greater patient workloads and to use resources efficiently.

The planning and management of unit-level activities in health care involve what has been referred to as technical work. To support the cognitive load of technical work, acute care practitioners, including ED staff, have developed physical cognitive artifacts[3] including status boards, schedules, and checklists to capture, use, and convey information. These artifacts support a distributed cognition,[4] which is a ''commonly shared knowledge that benefits a group but cannot be known by any single individual.'' Figure 1 describes both the individual and social senses of distributed cognition as well as the multiple roles that cognitive artifacts play.

The development and use of cognitive artifacts make it possible to perform the otherwise impossible process of care coordination for the ED patient population. As the patient length of stay and the number of procedures increase in the ED, the need for more powerful cognitive artifacts also grows in order to support increased demands for patient care coordination. As the use of information technology (IT) grows in the ED community, it may help to be aware of potential difficulties as well as an approach that promises to assist new digital artifact development.

## HOW TECHNOLOGY MAY AND MAY NOT WORK

Pressure is strong to adopt new IT in the interest of improvements to ED work environment efficiency and reliability. Because they are a smaller size and are unique compared with other units, EDs are less likely to be included in applications of large software programs. Some EDs have developed ''homegrown'' digital artifacts on their own or in cooperation with smaller IT firms that operate independently from larger information systems. In both cases, the prospects for work process improvement are accompanied by technology-related issues that also deserve consideration.

Multiple accounts[5,6] have described large-scale failures in health care automation, and others[7] question whether automation interventions actually increase the productivity of health care professionals. Optimism about what can be accomplished can float free from possible shortcomings, because difficulties are realized only after an application has been installed or has failed during development.[8] This is in part due to unintended consequences that occur during the application of technology but cannot be foreseen.

The reasons why IT applications can encounter shortcomings are varied and complex. First, automated information systems that rely on others to develop and implement changes can be less flexible than their manual precursors. This is because large costs are required to adapt generic software to the unique character of the local operating environment, which can make an organization resistant to making updates or adjustments to software. Second, automated systems may be more removed from practitioner experience. In larger organizations, they are often within the control of an IT department at the blunt end of the organization rather than controlled by practitioners at the sharp end. Third, automated systems can induce and reflect changes in the social structure of the organization. This can disenfranchise some while empowering others, often in ways that an organization would not deliberately do otherwise.[9] Fourth, applications that have been successful on a small scale can become unwieldy when their requirements and features scale up. Finally, automation makes work processes more ''brittle.'' This is because automated systems tend to reduce the frequency of small failures. When the systems do fail, they do not degrade gracefully. Instead, they fail catastrophically and without warning.[10] In other words, they do not bend, but rather break.

Practitioners confront problems that are subtle. They make trade-off decisions among difficult choices. Because of this, technology-driven approaches to information display are often conducted

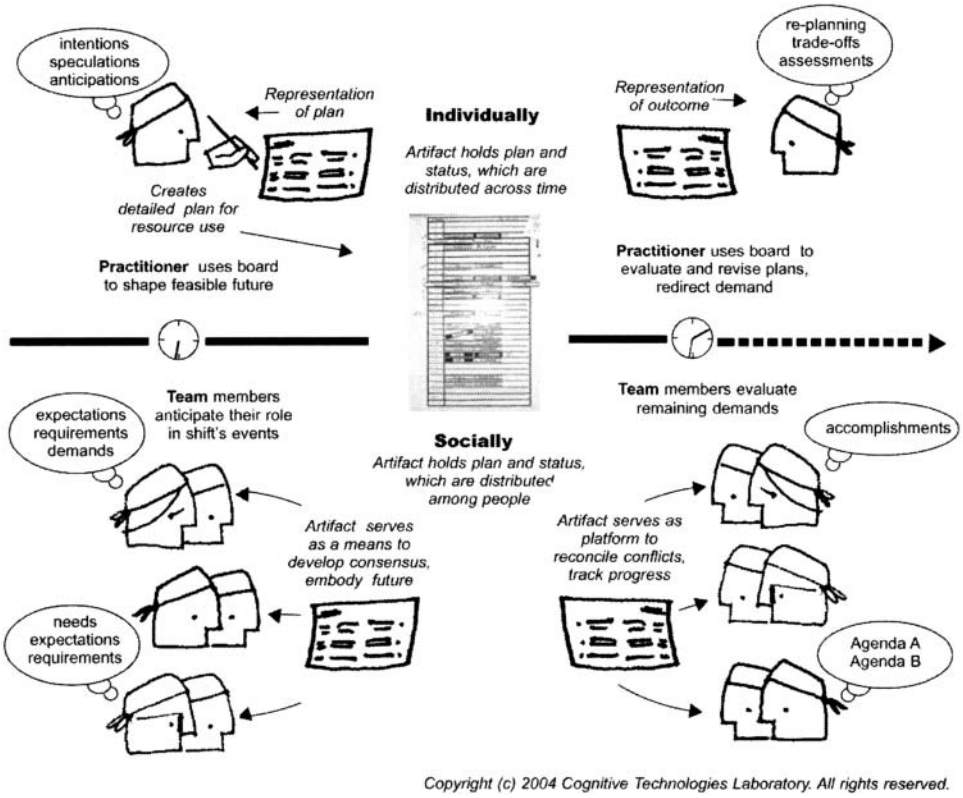


**Figure 1.** Distributing cognition individually and socially. Reprinted with permission of the Cognitive Technologies Laboratory.

without regard for the subtle, optimal approaches that practitioners have evolved to accomplish their work. This can result in information systems that are not well attuned to what ED staff members need during the periods of high-tempo operations. Further, technology can give the illusion of helping practitioners while at the same time creating "a new layer of burdens and complexities."[11] Having to do extra tasks to operate the automation can actually increase workload through what Weiner termed "clumsy" automation.[12] Outcomes that get in the way of practitioners can threaten to squander constrained resources, impede patient care, and erode medical safety.

The potential for a mismatch between work and IT also becomes evident when considering the nature of the ED environment and of automated systems. Aviation is often cited as a source for operational and control models that might be applied to health care. In particular, air traffic control (ATC) is mentioned as an example that health care automation might follow. However, on closer examination, it becomes apparent that ATC is a well-bounded domain that follows prescribed procedures. When circumstances become marginal and overtly threaten safety, it is acceptable (and expected) that operations are suspended. The automated systems that support ATC are relatively well suited to such well-bounded problems. Even in this well-bounded setting, automation has not proven to be a panacea. Controllers frequently rely on paper artifacts,[13] and an ambitious advanced automation system effort to upgrade the U.S. ATC computer system in the mid-1980s was "sunk by unrealistic specifications and human factors difficulties, among other problems."[14]

In contrast with ATC, the ED setting is highly variable, evanescent, contingent, uncertain, poorly bounded, resource constrained, and beholden to many external influences. For example, patients just "show up." In order to reconcile care resources with patient care demands, ED teams routinely engage in fluid, dynamic cognitive activities that require flexible, reliable artifacts to support them. They seek, track, digest, calibrate, probe, evaluate, verify, and share information. They also plan, speculate, replan, and make trade-off decisions. No circumstances make it acceptable to suspend patient care. Because of this, practitioner teams have developed a range of sophisticated strategies to manage the balance between work and demand. In order to succeed, automation needs to be a team player in the ED setting.

Even in a relatively well-controlled health care environment, making automation a team player is a challenge. Even though it is not an ED, this brief example illustrates the kinds of problems that can occur during the conversion of an anesthesia-assignment master schedule from paper to electronic display.[15] A physical version of a master schedule had made it possible for the coordinator in an acute care anesthesia department to control the accuracy of

information that was used to make decisions. Only the coordinator would make marks on the one original hard copy that was posted at the coordinator station. The physical artifact also allowed for the coordinator to make margin notes to keep track of unofficial yet important information such as the name and extension of a staff member who had called with information that pertained to a case. The conversion of the master schedule from a physical to a digital artifact has had a number of consequences. Now, many elements of information have been truncated, so details can be found only by drilling down through multiple levels of the interface. Much of the fine-grained detail on changes, such as when they were made and who made them, is no longer available. The operating room nurse is now responsible for reporting patient arrival in the operating room by laptop, at the moment when all attention is focused on preparing the patient and the operating room for the upcoming procedure. The resultant lag in case status causes the coordinator to second-guess the display and do additional cognitive work to check on case status and erodes confidence in the coordinator as the pivotal decision maker. As case status changes throughout the day on the electronic display, the location on the screens also changes, requiring team members to search across multiple display screens to find them.

These and other difficulties can be better handled by understanding how practitioners plan and manage the technical work of the unit.

## COGNITION RESEARCH: THE ED

More structured domains such as ATC can rely on automated systems for computer aiding. Identifying aircraft, solving relative motion problems, and resolving conflicts within the airspace are valuable assistance for controllers. However, the ED is a more complex setting than ATC and practitioners engage in work that is much more complex.

Greater complexity in a setting such as the ED requires greater complexity to manage it.[16] Rather than the problem solution that fits ATC, ED staff as a group needs displays that make it possible to see the whole problem and then collaborate on solutions. IT-based displays are flexible and can be used to support cognitive work in the ED. However, this does not happen automatically. To make the most of what technology has to offer, the design of the digital artifact must represent constraints and opportunities that are relevant in the ED. Both can be derived through observational research. Observation has benefits over focus groups and interviews. Artifacts are so thoroughly integrated into practitioners' work that they rarely receive a detailed analysis by the people who use them. Practitioners can find it difficult to articulate the complex and varying ways they work and are so intimate with their work environment that it is easier for an informed outsider to view it objectively.

Performing research such as this reveals information about the work setting that might redirect detailed studies of technical work. Results can be used to create displays that are well suited to ED staff work. Findings can also show how to create other types of displays that might add value. For example, patient displays are typically organized according to location. However, most of the cognitive work that staff members perform is temporal. What has happened, what has been set in motion, what can be expected, and when each occurs is best depicted in time series representations. Because time is the key aspect here, designing a display according to time allows staff to easily track changes, anticipate future events, and respond to emerging situations. Electronic displays can also support prompting, speculation, consequence assessment, and value-based decisions in ways that physical artifacts cannot.[17]

## CONCLUSIONS

Recent research has shown how health care practitioners develop and use physical cognitive artifacts.[18–21] Cognitive artifacts are an efficient representation of what matters in a work domain because they represent only the information that is critical. Findings from field observations and from controlled studies that incorporate cognitive artifacts can be used to guide the development of authentically user-centered automation.[22]

Information technology can help or hinder cognitive work. Confidence over the potential for IT must be balanced by caution over its potential difficulties. Current research now under way in health care settings shows how practitioner technical work can be understood through the physical artifacts that they create and use. The use of such approaches promises to avoid the shortcomings of previous IT misadventures. It also promises to build genuinely valuable solutions, not just IT experiments, to support ED cognitive work.—**Christopher Nemeth, PhD** (cnemeth@uchicago.edu), **Michael O'Connor, MD, Richard Cook, MD,** *Cognitive Technologies Laboratory, University of Chicago, Chicago, IL;* **Robert Wears, MD, MS, Shawna Perry, MD,** *Department of Emergency Medicine, University of Florida, Jacksonville, FL.*
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