Expertise Coordination and Information Technology in High Velocity Work Environments[+]

(National Science Foundation Award ITR- 0081868)

Final Report

May 2005

Yan Xiao, PhD*, *University of Maryland, Baltimore*
Samer Faraj, PhD, *University of Maryland, College Park*
Colin F. Mackenzie, MD, *University of Maryland, Baltimore*

*Human Factors and Technology Research
University of Maryland School of Medicine
685 W. Baltimore St., MSTF 534
Baltimore, Maryland 21201
URL: http://hfrp.umaryland.edu
Email: yxiao@umaryland.edu

+ Suggested citation: Xiao Y, Faraj S, Mackenzie CF. *Expertise Coordination and Information Technology in High Velocity Work Environments-Final Report.* University of Maryland, Baltimore, 2005. On-line access to the report: hfrp.umaryland.edu/research.

Abstract of the Project Proposal

High velocity work environments such as medical trauma centers depend on robust and efficient coordination by team members to bring together appropriate knowledge and skills, or expertise. This project investigates the existing and potential role of information technology (IT) in expertise coordination in a type of high velocity, high outcome work environments: level-I trauma centers in this country. A combination of qualitative and quantitative methods are used to collect observational and survey data in a range of trauma centers regarding: the expertise needs of trauma medical teams, the points of expertise needs, the modes of acquiring needed expertise, the sources of information related to work and expertise coordination, uses of IT for the coordination of needed expertise, as well as broader organizational variables. The project will contribute to the development of guiding principles in the design of next generation IT for high velocity work environments in the areas of user interfaces, contents, coordination mode, and evaluation of the impact of IT on coordination. It will contribute to the understanding of expertise coordination and how IT affects its processes. Finally, the project will enhance an existing multi-disciplinary research program on information and coordination related issues in emergency trauma care.

Project Participants

Project Director
Yan Xiao, PhD[1]
Human Factors & Technology Research
Department of Anesthesiology
University of Maryland School of Medicine

Co-Principal Investigators
Samer Faraj, PhD[1]
Decision and Information Technology
Smith School of Business
University of Maryland, College Park

Colin Mackenzie, MD[1]
National Study Center for Trauma and Emergency Medical Systems
University of Maryland School of Medicine

Brian Gugerty, PhD
University of Maryland School of Nursing

John Welton, PhD
University of Maryland School of Nursing

Graduate Research Assistants
Cheryl Plasters, RN, MBA[1] (nursing)
Young-Ju Kim, RN[1] (nursing)
Jacqueline Moss, RN[1](nursing)
Janet Lee, RN[1](nursing)
Jerry Chamberlin, RN (nursing)
Hao Hu (computer science)
Angel Lu, RN, MBA (nursing)
Anadi Mahajan (computer science)
Rebecca Roys, RN (nursing)
Kathleen McGrow, RN (nursing)
LeAnthony Mathews, RN (nursing)
Angu Sidu, BA (medicine)
University of Maryland, Baltimore

Sharyn Gardner[1](Management)
Seokhwa Yun[1](Management)
Tongxiao Zhang[1](Management)
Smith School of Business
University of Maryland, College Park

Post Doctoral Fellow
Anne Miller, PhD[1]
The University of Queensland, Australia

Research Experience for Undergraduate Students
Eric Boehm[1]
University of Maryland, College Park

Sung Park[1]
University of Maryland Baltimore County

Other Collaborators
F. Jacob Seagull, PhD
Peter Hu, MS, CNE
Roger Voigt, MD
Sherry Perkins, PhD
Richard Dutton, MD
Tim Gilbert, MD
School of Medicine
University of Maryland, Baltimore

Peter Wieringa, PhD
Delft University of Technology, the Netherlands

---

[1]Worked for more than 160 hours in any one year of the project.

Research and Education Activities

Research Activities

The overall objective of this project was to systematically investigate the role of Information Technology (IT) in supporting the coordination of expertise in a type of high velocity, high outcome work environments: trauma centers in the USA.

The study addressed two core questions. First, what are the coordination practices used by organizations that operate in high velocity environments and must operate safely? Second, how does the use of IT affect coordination and organizational outcomes? We positioned this research at the intersection of the environments described by high reliability organization theory as driven by error free operation and the high velocity decision making environments described by Eisenhardt and colleagues. We suggested that both formal and improvised coordination processes are of value in such settings and that an understanding of coordination requires a focus on communities of practice and boundaries. Based on observation and theory, we also suggested that IT plays a crucial role in facilitating coordination by supporting timely information sharing, by allowing one-to-one and one-to-many communication when time is limited.

In addition to theoretical work, three lines of research activities were carried out.

a) A qualitative investigation of coordination. We conducted observational and interviewing studies in 12 trauma centers located throughout the country. At each site, we observed trauma admissions and work coordination. We also undertook in-depth interviews with 8-12 key participants at each site. The interviews were semi structured and lasted up to 90 minutes. The interviews form the basis of a deeper understanding of how coordination varies across settings and work environments. Additionally, we performed in depth studies (beyond what was carried out in an earlier NSF funded project – IIS 9900406) at the University of Maryland's Shock Trauma Center, a leading US trauma center.

These qualitative studies led to new concepts of coordination in high velocity organizations (e.g., [1;2]), high reliability team coordination (e.g., [3-5]), and the role of artifacts in supporting coordination (e.g., [6;7]). Some of the insights gained guided the design of and field experimentation with tools supporting coordination in high velocity environments [8-10].

As designed, one of the objectives of the qualitative work was to design a nationwide survey of trauma centers in terms of expertise coordination practices and use of information technology. A key design question for the planned survey study was what type of centers would be chosen for inclusion in the survey. To achieve that, we sampled a wide range of trauma centers to visit (freestanding centers vs. trauma functions embedded in an emergency department, urban vs. rural and low volume vs. high volume).

b) A survey-based data collection effort of all level-one and level-two trauma centers in the USA. Through consultation with leading experts in trauma systems, we designed a set of comprehensive survey instruments on key aspects of expertise coordination, such as organizational factors, use of information technology for expertise coordination, and

existing procedures for expertise coordination. Three types of surveys were developed, one for the director of the trauma program in a trauma center (usually a physician trained in trauma surgery or emergency medicine), the coordinator of the trauma program (usually a nurse), and clinicians (we aimed at physicians of different specialties and nurses). The instruments were piloted tested.

Through careful planning and extended efforts, the mail survey portion of the project was accomplished successfully. For example, there was no official list of all Levels I and II trauma centers for the whole country. We contacted each of the 50 states' emergency medical service authority to compile the list. The Survey was sent to 456 level I and II trauma centers in the US. About two thirds of the centers (308/456) responded, with participation from 254 trauma directors, 212 trauma coordinators, and 767 trauma clinicians. About one third of the centers (120/456) completed all requirements (survey responses from the director, the coordinator, and at least three clinicians).

The result was a uniquely rich data set covering the topic of IT use in trauma care. Part of the results was reported in a PhD dissertation (Gardner) and will be presented in the upcoming Academy of Management annual meeting. We finished the data analysis and anticipate continual publication efforts (e.g., [11]). The results on the use of communication technology for timely assembling of expertise were reported in a paper recently accepted for publication [12].

Although not part of the proposed work, we sought methods to link expertise coordination and outcomes. In addition to the data collected through the survey methods, we requested and received approval from the American College of Surgeons (ACS) to use a patient outcome centered national database on trauma patients. The database is known as National Trauma Data Bank (NTDB). Over 100 trauma centers volunteer to participate in the reporting of trauma patient outcomes to NTDB. NTDB is updated annually. We had obtained agreement from ACS to link the data in NTDB and our survey data through an aggregation method to remove privacy concerns from reporting trauma centers. Such linkage will enable us to understand the impact of expertise coordination on patient outcomes.

c). Coordination in managing schedules in high velocity work environments. This line of activities was initiated by an earlier project (NSF award IIS 9900406). The focus was on the coordination practices used in managing schedules of a trauma surgical operating room suite. The suite had the mission of providing surgical services to trauma patients, who often need emergency, life-saving operations and at other times need less time pressing operations. Managing the schedules in the suite is an exemplary task in high velocity work environments. Through a combination of methodologies (observation, shadowing and in-situ interviews), we observed the challenges of coordination in such a setting as well as the practices adopted to meet the challenges [13-15]. Some of the practices required heavy communication workload, as captured in a study of communication patterns [16;17]. The practices may be in part an adaptive response to temporal patterns in external events, as suggested by a study on coordination activities as related to seasonal patterns of trauma patient admissions [18]. The nomadic nature of workers in high velocity work environments place stringent requirements on information technology solutions (e.g., portable computing devices), yet current solutions were poorly suited when clinicians were asked or observed [19].

Education Activities

As planned, the project provided an excellent platform for education activities for students from a variety of backgrounds (see student sections on Project Participants). The project team leveraged the platform extensively and involved students from nursing, computer science, business management, and medicine. The enthusiastic responses from students of such a variety of backgrounds were beyond expectation, and were a direct benefit from collaboration of researchers from multiple disciplines and from multiple institutions. The topic of coordination is also a cross-cutting issue for many domains. These aspects of the project fulfilled some of the inspiration of NSF's Information Technology Research initiative.

A total of 6 doctoral students worked on the project (Yun, Gardner, Moss, Plasters, Lu, and Kim). Two dissertations (Gardner & Kim) were essential part of the project. One dissertation was on organizational flexibility (Gardner), and the other is on-going and is on modeling of relations between timeliness of surgery and outcomes in head trauma surgery (Kim). The project attracted 10 Master's degree level students. Additionally, a visiting post-doctoral researcher (Miller) participated in the project by conducting a study on temporal patterns of coordination [18].

The project team carefully designed student projects to encourage their learning while at the same time to involve the students in research in substantive ways. As evident by the project publications, students have contributed greatly to the project.

We would like to highlight the involvement of a master degree nursing student, Mr. Chamberlain. This student worked closely with a PI and developed a case example of an information technology solution (12 lead ECG field telemetry) to illustrate the interplay between information technology, expertise coordination, and technology adoption processes. The materials have been used in a course development.

An anesthesiologist (Gilbert) who was also a Masters Degree student in a management information system program selected one of the PIs (Faraj) as thesis advisor. The project provided this student an exciting training opportunity. Through interaction with the project team, he developed a survey to study the relationship between coordination and information technology in the management of operating rooms. The results of the survey are being written up for publications.

Findings

The results from the project-related research activities have provided valuable insight into expertise coordination in high velocity work environments. We will summarize the key findings in the following 9 areas.

1. **Emergent practices** [1]. Organizational coordination has traditionally been viewed from an organizational design perspective where rules, modalities, and structures are used to meet the information processing demands of the environment. More organizations than ever are facing highly uncertain task environments that require fast decision-making where mistakes can be catastrophic. Because expertise is distributed and interdependencies are rapidly evolving, we argue that such environments benefit from practices that effectively coordinate expertise and support failure-free operation. Our research on coordination practices was based on a medical trauma center where fast response and error free activities are essential requirements. We found that expertise coordination practices are necessary due to

the distribution of expertise and the highly situated nature of trauma work. Furthermore, because specialists are embedded in communities of practice and the tempo of treatment is high, there is a need for dialogic coordination practices that ensure error-free operation. The practices include: administrative structuring mechanisms whose structuring role varies depending on the immediate environmental conditions; interacting communities of practice that absorb much of the organizing needs and thus free up scarce organizational resources; and expertise coordination processes that ensure patient safety by managing knowledge and skill interdependencies.

2. **Transactive responsibility system** [3-5]. Understanding how teams perform successfully in high-risk settings can provide us with insights into the processes by which safety is created. Building upon previous field and laboratory studies, we proposed a tentative formulation of a concept, *transactive responsibility system,* to account for the intricate, complex responsibility system emerged in team interaction. With a transactive responsibility system, a team can deal with the challenges of conflicting goals of training and performing and rapidly changing work environments found in many settings. Guided by the phenomena uncovered in field studies, we identified cultural and institutional conditions for high reliability teams, in particular related to how reliable performance is achieved through active mutual adjustment to detect and compensate vulnerabilities to reliable performance..

3. **Resolution and bandwidth of workplaces** [6;7]. In any collaborative work settings, people naturally develop physical tools and associated work processes that support the management of the interdependencies in information, materials, and social needs. Field studies of management of operating rooms pointed out that collaborative work is supported by an infrastructure that is composed of mostly non-computerized, physical components. The supporting infrastructure is jointly maintained and exploited, with constantly evolving patterns of usage, in response to complexity of coordination needs and the uncertain environment. To represent status and plans, users seem to invent structures based both on idiosyncratic preferences and on negotiated symbols. The fluidity and ease of restructuring workplaces to support collaborative work may be explained in part by the high resolution and bandwidth of workplaces: a large number of ways in which workers could structure their work and a high capacity to convey rich information and meanings quickly to collaborators.

4. **Technology embedded communal display** [9;10]. Healthcare environment is a prime example of collaborative work, in which work is organized both at the macro-level over days and weeks as well as micro-level over hours and minutes. Coordination is carried out jointly by those who often share the ultimate goal of providing best care to the patient while at the same time have different perspectives. Additionally, uncertainty and contingencies often arise to disrupt the best plans. Based on the phenomenology observed in coordination for operating room management, we developed a video-based toolset and conducted field experimentation in a Level-I trauma center to enhance distributed monitoring. Initial trials showed that the toolset was very well received.

5. **Operational flexibility** [20]. This is part of a dissertation research. Organizations are currently facing increasingly dynamic environments that require fast action in high-velocity settings. Recent research on dynamic capabilities purports that

organizations need to build these capabilities to successfully confront increasing uncertainty. Operational flexibility was defined as the ability of subunits to change day-to-day or within a day with the operational problems and changes. A model was developed and tested of subunit design factors and information sharing relationships with operational flexibility and in turn subunit performance. Using hierarchical regression analysis of a national survey of trauma centers, results indicate that subunit design factors and information timeliness and accessibility are significantly related to operational flexibility. Additional analyses further show that these subunit design factors are also related to subunit performance. Results also indicated that operational flexibility was not related to subunit performance, yet a combined operational flexibility index was.

6. **Information and communication technology and expertise coordination** [11;12]. Coordination in high velocity work environments is challenging and unique for several reasons. Workload input is unpredictable with large variations from time to time. Activities are event driven and are highly time sensitive (e.g., the concept of the "golden" hour in trauma care). Activities are frequently coordinated among different organizations of several tiers over distant geographic locations. Work is usually resource intensive and expertise intensive. These challenges highlight the essential role of information and communication technology (ICT) in the coordination. The results from the survey of national trauma centers demonstrated that certain types of ICT were used actively in expertise coordination in that cellphones, overhead pagers, and radios were essential in assembling of needed expertise in rapid responses to the of trauma services. These types of technology were used because of their reliability, even they were in general more interruptive as compared to asynchronous communications, such as text pagers and images transfers. The expertise coordination was a combination of procedural responses and negotiation through the use of ICT. As a part of the trauma care coordination, a study of relationships between time from trauma center arrival to surgery and patient outcomes is on-going [21]. This study will investigate organizational factors influencing time to surgery and subsequently provide significant practical standards for management of patients with head injury.

7. **Collaborative coordination** [13-15;22]. The complexity of large-scale technical and collaborative work-systems requires significant effort for coordination, and balancing off the differing individual actors' goals and information needs. The process of coordinating a suite of surgical operating rooms (ORs) is one example of such as complex system. Examining the information usage in this setting can provide functional requirements for technology to support these coordination activities. Data from observations and interviews in an OR suite were synthesized into five principal functional requirements for such a technology system. To provide necessary functionality, any new technology system must (a) serve as catalyst for collaborative and distributed cognition, (b) provide a communal memory tool for planning (c) serve as catalyst for collaborative and distributed cognition (d) allow parallel manipulation for multiple user-groups, (e) allow flexible content-reconfiguration.

8. **Communication patterns** [16;17]. Technological applications can be used to change system processes to improve communication and information access, thereby decreasing errors and adverse events. The successful design of such applications relies on an understanding of communication patterns among healthcare professionals. Charge nurse communication was observed and documented at four

OR suites at three tertiary hospitals. The data collection tool allowed rapid coding of communication patterns in terms of duration, mode, target person, and the purpose of each communication episode. Most (69.24%) of the 2074 communication episodes observed occurred face to face. Coordinating equipment was the most frequently occurring purpose of communication (38.7%) in all suites. The frequency of other purposes in decreasing order were coordinating patient preparedness (25.7%), staffing (18.8%), room assignment (10.7%), and scheduling and rescheduling surgery (6.2%). The results of this study suggest that automating aspects of preparing patients for surgery and surgical equipment management has the potential to reduce information exchange, decreasing interruptions to clinicians and diminishing the possibility of adverse events in the clinical setting.

9. **Temporal plasticity** [18]. We present the concept of temporal plasticity to describe the efforts of coordinators to stretch and adjust regularly occurring patterns of work to accommodate unplanned events. Temporal plasticity extends Anselm Strauss's concept of Articulation work, which involves the temporal aspects of cooperative work in terms of recurrent patterns or rhythms. Recurrent patterns simplify coordination by shaping individuals expectations about sequences of events. Using recurrent patterns of activity, neither coordinators nor those being coordinated need specific processes to inform them about what happens next – having seen it many times before they already know. However rhythms also constrain activity by setting temporal boundaries especially on the availability of resources. Accommodating unplanned events involves distorting routine rhythms based on knowledge of the rhythm and the resource capacities within which the rhythm operates.

Training and Development

The project was designed to maximize the impact on training and development, as outlined in the "Education activities" section. The achievement in training and development can be separated into five areas according to the level of training.

Faculty. Dr. Seagull joined the University of Maryland as a faculty member after the start of the project. Through the project, he was trained to conduct field studies related to coordination and contributed significantly to the project (e.g.,[22]). As a result of participating in the project, he was a co-PI in an NSF funded project on large scale collaboration. Although Dr. Seagull was trained as an engineering psychologist, the project provided him with the opportunity to leverage his background in display designs in coordination research.

Dr. Faraj was promoted recently to Associate Professor, in part based on the research activities associated with the project.

Post-doctoral fellow. Dr. Miller had a nursing background and earned a PhD in human factors on a project studying information exchange in intensive care units. During her tenure as a post-doctoral fellow for the project, she gained knowledge in coordination studies in general and field research methodologies. Although her time on the project was short (only 3 months), she identified an interesting and key aspect of coordination in high velocity work environment: temporal rhythm management [18]. She is currently at the University of Queensland, Australia.

Doctoral students. In addition to a dissertation [20] directly related to this project, another dissertation is developed based on the results of this project [21]. Five other doctoral students participated in the project. They brought with them unique background and contributed in unique ways through examining the topic of coordination based on their training and professional perspectives. In general they learned in first hand the value and benefits of multi-disciplinary research, a hall-mark of the Information Technology Research initiative. While learning field research methodologies, they were also exposed to the areas of information technology and expertise coordination, which will play ever more important role in the information and knowledge based economy. We were especially proud of their scholarship achievement as evidenced by peer reviewed publications. We believe the project provided unique value to their education.

Master's students. Eight Master's students were involved in the projects from a variety of backgrounds. We think the project contributed to their education in a unique way. For computer science students, the project taught them about non-technical aspects of information technology, and understanding the potential contribution of information technology in complex work environments where stakes are extremely high. For students with clinical background, the project allowed them to examine the work they were familiar in a new angle: how work was coordinated and how to think the role of technology, not just as computing devices, but tools for collaborative work. While on this project, they furthered their own background through programming and observing health work, and gained new perspective of collaborative work.

Undergraduate students. The project had attracted two undergraduate students through the Research Experience for Undergraduates (REU) program. Both students, because of their engineering background, learned to prototype tools to support collaborative work and expertise coordination.

Outreach activities

1. The PIs (Faraj & Xiao) organized a high visibility symposium during the Academy of Management annual meeting (2002, Denver, CO). The syposium was jointly sponsored by 3 divisions of the Academy (OCIS-Organizational Communication & Information Systems, TIM-Technology & Innovation Management, and HCM-Health Care Management) and received the rare and valuable "showcase" status.

2. Dr. Xiao visited Carnegie-Mellon University in December 2002 to give a colloquium lecture to graduate students in CMU's HCI Institute. During the visit Yan met with Linda Argote, Susan Fussell, Sara Kiesler and Bob Kraut for information exchange on possible collaboration. A new joint ITR proposal was submitted based on the collaboration

3. Leadership of high reliability teams, teaching case, 2001. Prof. Henry P. Sims, University of Maryland College Park. (The data collected in the project was used in graduate and executive education programs).

4. During the Human Factors & Ergonomics Society Annual meeting in Baltimore (October, 2002), Yan's research group hosted a lab visit to those interested in coordination research. We demonstrated a videoboard developed in part as a tool to explore large scale coordination.

5. Yan Xiao visited two international trauma systems, one in Germany (Regensburg) and on in China (Beijing). Because of differences in how EMS systems are financed, these two visits provide a broader view of the issues involved in coordination.

Publications

There are a total of 14 papers published in peer reviewed journals and conference series proceedings, 3 papers accepted in peer reviewed journals, 1 book chapter, and 4 other papers under preparation. Student participants in dessimination were indicated by underlines.

Journal and proceeding articles

1. Xiao, Y., & Moss, J. Practice of High Reliability Teams: Observations in Trauma Resuscitation. *Proceedings of Human Factors and Ergonomics Society 44th Annual Meeting,* p. 395-399, 2001.
2. Moss, J., Xiao, Y., & Zubaidah,S. The operating room charge nurse: Coordinator and communicator. *Journal of American Medical Informatics Association*, 9(6 suppl):S70-S74, 2002
3. Xiao, Y., Gagliano, D., Hu, P., Mackenzie, C. F., & Alcorta, A. Video-Assisted Coordination for Field-Hospital Communication. *European Journal of Medical Research*, 7(1):94, 2002
4. Xiao, Y., Moss, J., Mackenzie, C.F., Seagull, F.J., & Faraj, S. Transactive responsibility systems and high reliability teams: a tentative formulation. *Proceedings of Human Factors and Ergonomics Society 46th Annual Meeting*, 1428-1432, 2002
5. Xiao, Y, Seagull, J.F., Faraj, S., & Mackenzie, C.F. Coordination Practices for Patient Safety: Knowledge, Cultural, and Supporting Artifact Requirements (Macroergonomics in Healthcare: Session). Proceedings of International Ergonomic Association 2003.
6. Seagull, J.F., Xiao, Y., & Plasters, C. Distributed Planning Over Time and People: Balancing Sampling Effort and Information Accuracy. *2003 Proceedings of IEEE International. Conference on Systems, Man, and Cybernetics*, pp. 1772-1777, 2003.
7. Xiao, Y, Seagull, J.F., Hu, P., Mackenzie, C.F., & Gilbert, T.B. Distributed Monitoring and a Video-Based Toolset. *2003 Proceedings of IEEE International. Conference on Systems, Man, and Cybernetics*, pp. 1778-1783, 2003.
8. Xiao, Y, Seagull, J.F., Hu, P., Mackenzie, C.F., de Visser, J., & Wieringa, P. Distributed Monitoring In a Dynamic Environment: Trade-Offs of Information Access and Privacy. *2003 Proceedings of IEEE International. Conference on Systems, Man, and Cybernetics*, pp. 4141-4146, 2003
9. Seagull, J.F., Plasters, C., Xiao, Y., & Mackenzie, C.F. Collaborative management of complex coordination information systems: operating room schedule coordination. *Proceedings of the Human Factors and Ergonomic Society 47th Annual Meeting, Denver, Colorado*, pp. 1521-1525, 2003.
10. Plasters, C. L., Seagull, F. J., & Xiao, Y. Coordination Challenges in Operating-Room Management: An In-Depth Field Study. *Proceedings of the American Medical Informatics Association Symposium*, Washington, DC, 524-528, 2003
11. Lu YC, Lee JK., Xiao Y, Sears A, Jacko J, & Charters K. Why Don't Physicians Use their Personal Digital Assistants? *Proceedings of the American Medical Informatics Association Symposium*, Washington, DC, 405-409. 2003

12. Moss, J., & Xiao, Y. Improving Operating Room Coordination: Communication Pattern Assessment. *The Journal of Nursing Administration*: 34(2):93-100, 2004
13. Seagull, F.J., Xiao, Y., & Plasters, C. Information Accuracy and Sampling Effort: A Field Study of Surgical Scheduling Coordination. *IEEE Transactions on Systems, Man, and Cybernetics, Part A:Systems and Humans.* 24(6): 764-771. 2004
14. Xiao, Y., Plasters, C.L., Seagull, F.J., & Moss, J.A. Cultural and Institutional Conditions for High Reliability Teams. *Proceedings of the IEEE Conference on Systems, Man, & Cybernetics. 2580-2585. 2004*

One-time publications (Book chapters):

- Xiao, Y., & The LOTAS Group. Understanding Coordination in a Dynamic Medical Environment: Methods and Results. In M. McNeese, E. Salas, & M. Endsley (Eds.): *New Trends in Collaborative Activities: Understanding System Dynamics in Complex Environments,* Santa Monica, CA: Human Factors and Ergonomics Society, 242-258, 2001

Accepted publications

1. Xiao Y, Kim YJ, Gardner SD, Faraj S, Mackenzie CF. Communication Technology in Trauma Centers: A National Survey**.** *Journal of Emergency Medicine. 2005*
2. Xiao Y, Seagull FJ. Emergent CSCW Systems:The Resolution and Bandwidth of Workplaces**.** *International Journal of Medical Informatics. 2005*
3. Faraj, S. & Xiao, Y. Coordination in fast response organizations. *Management Science*. (Second revision)

Manuscript under preparation

1. Kim YJ, Xiao Y, Mackenzie CF. Availability of Human and Facility Resources in Level I and II Trauma Centers. *Journal of Trauma.*
2. Xiao Y, Plaster CL, Moss J, Faraj S. Transactive Responsibility Systems. *British Medical Journal*
3. Xiao, Y, Seagull FJ, Faraj S. Dynamic Reconfiguring of a Communal Display to Support Rapid Coordination. *Journal of Collaborative Computing*.
4. Miller A & Xiao, Y. It's about time: Temporal rhythms in large-scale coordination problems. *International Journal of Human-Computer Studies*.

PhD Dissertation

Sharyn Gardner. *Understanding Dynamic Capabilities at the Subunit Level: Operational Flexibility and the Crucial Role of Organizational Design and Information Sharing*. November 2004

Young-Ju Kim. *Time to Surgery and Outcomes in Head Trauma Patients*. May 2006 (Expected)

Major presentation

1. Samer Faraj (Session Chair). Coordination of Expertise in High-Reliability Work Environments: What Constitutes Effective Practice? Academy of Management Annual Meeting, Denver, CO, 2002
2. Samer Faraj & Sharyn Gardner. Expertise Coordination In High-Velocity High-Uncertainty Environments? Academy of Management Annual Meeting, Denver, CO, 2002
3. Yan Xiao and Colin F. Mackenzie. Study of team excellence: Practices of teams in high-velocity, high-stake environment. Academy of Management Annual Meeting, Denver, CO, 2002
4. Samer Faraj: "Coordination In Fast Paced Environments: Implications For Organizational Design" in the symposium titled "Revisioning Organization Design Theory: Alternative Perspectives." Academy of Management Annual Meeting, Seattle, August 2003
5. Yan Xiao: “Cognitive Properties of a Whiteboard”. Panel presentation, American Medical Informatics Association Fall Symposium, November 11, 2003
6. Yan Xiao, Information technology and coordination. Seminar presentation, Center for Technology in Government, State University of New York at Albany, July 16, 2004
7. Gardner, S.D. Dynamic Capabilities: Operational Flexibility, Organizational Design, and Information Sharing. To be presented at Academy of Management Annual Meeting, 2005

Internet

A project website was developed for dissimination of research findings: http://hfrp.umaryland.edu/coordination

Other specific products

A survey instrument to measure expertise coordination, use of coordinative information technology, organization flexibility, and perceived trauma team efficacy. The instrument was used in a national survey of all Levels I and II trauma centers.

A report of use of communication and information technology based on a national survey. The report will be available on-line in early June, 2005, at hfrp.umaryland.edu.

Contributions

The principal discipline

The results from this project contributed to several disciplines (due to the inter-disciplinary nature of the project). First and foremost, we contributed to the understanding of collaborative systems. Expertise coordination is a key challenge in high velocity work environment, and inevitably it is achieved by a combination of information technology and practices in collaborative systems. We contributed new concepts: emergent practices [1], transactive responsibility systems [3-5], resolution and bandwidth of workplaces [6;7], operational flexibility [20], and temporal plasticity [18]. These concepts help explain how expertise coordination is achieved in dynamic, high risk settings.

Secondly, we contributed to the design of collaborative systems. Information technology plays an ever more important role in expertise coordination. The reliability requirements in domains like trauma so far have relied primarily on synchronous communication [12]. Physical artifacts with no networked connections, some of them output from computerized information systems, are critical in the studied highly dynamic, highly collaborative domain [7;23]. The properties of these supporting tools uncovered by our studies provide insights to designs that harness the power of new information technology advances, and we indeed found that out in our field experimentation [9;10]. Designers of computer supported cooperative work (CSCW) systems can learn, based on our work, how the physical and perceptual properties of workplaces are exploited, as these exploitations result in more efficient and reliable collaborative systems.

Thirdly, we contributed to the understanding of high reliability organizations. We identified practices used in these organizations to achieve sustained safety through adaptive behaviors so vulnerabilities in such systems do not lead to adverse outcomes. These practices have direct implications to training and organizational designs, in terms of requirements for unit flexibility [20], for cultural environments and knowledge [5;20;24], and indeed for organizational design [1].

Other disciplines

In addition to those highlighted earlier, the project contributed to the field of trauma and emergency medical services. Part of the survey results was published in a journal with a traditional readership of healthcare [12], as the findings were directly relevant to important issues such as current status of communication technology and perception of the status [12], as well as expertise resources currently activated [11]. Successful field communication enables the trauma center reception team to be well prepared and aware of salient issues that may require preemptive planning (e.g., operating room availability). The survey of Level I and II trauma centers across the nation on communication modes is important as it reveals the commonly employed field technologies (short-wave radio), and in-hospital (paging and plain old telephone) are little changed since the 1970's [12]. This suggests that the time is near for deployment of more advanced technologies, such as cell phones (duplex, hands-free communication) and of digital images. More passive and accurate methods of communication are needed to unburden the multi-tasking field first responder, such as the transmission of trends in vital signs and automation of injury severity status assessment. Such additional communications can better prepare the

hospital first receivers to coordinate personnel, resources and responses for optimal trauma patient resuscitation.

We believe that the project also contributed to the field of patient safety. Health care organizations are complex and require expertise coordination, often under resource and time stress. The practices [1;3;24] identified provide guidelines of how trauma and intensive care unit teams could be organized to minimize coordination failures.

Development of human resources

The project contributed in significant ways to the development of a research infrastructure at the University of Maryland School of Medicine. Traditionally research on collaborative systems and organizational issues coordination is not part of medical schools. The project brought recognition of non-biomedical research in a medical school. It strengthened the collaboration between researchers from different institutions.

Resources for research and education

The project brought significant amount of resources in several ways. The field research well established a “laboratory” for coordination studies in a leading trauma center, with strong support from the center’s administration and staff. Such support is invaluable for continuing and future research related to collaborative systems.

There were significant synergistic activities between the project and other projects. As such, the project contributed to the general research and education environment in the three collaborating institutions (medicine, nursing, and business). In particular, the Human Factors and Technology Group at University of Maryland, Baltimore was conducting related research on team leadership, patient safety, and new technology to improve workflow in surgical operating rooms. The project provided theoretical foundations to some of the synergistic activities as well as ideas for new projects.

Contributions beyond Science and Engineering.

See the section “Other disciplines.”

Reference List

[1] Faraj.S., Xiao Y. Coordination in fast response organizations. Management Science 2005; (accepted for publication).

[2] Xiao Y, The LOTAS Group. Understanding Coordination in a Dynamic Medical Environment: Methods and Results. In: McNeese M, Salas E, Endsley M, editors. New Trends in Collaborative Activities: Understanding System Dynamics in Complex Environments. Santa Monica, CA: Human Factors and Ergonomics Society, 2001: 242-258.

[3] Xiao Y, Moss J. Practice of High Reliability Teams: Observations in Trauma Resuscitation. Proceedings of Human Factors and Ergonomics Society 44th Annual Meeting. Minneapolis/St. Paul, MN: Human Factors and Ergonomics Society, 2001: 395-399.

[4] Xiao Y, Moss J, Mackenzie CF, Seagull JF, Faraj S. Transactive responsibility systems and high reliability teams: A tenative formulation. Proceedings of Human Factors and Ergonomics Society 46th Annual Meeting. Baltimore, MD: Human Factors and Ergonomics Society, 2002: 1428-1432.

[5] Xiao Y, Plasters C, Seagull JF, Moss J. Cultural and Institutional Conditions for High Reliability Teams. Proceedings of the IEEE Conference on Systems, Man, and Cybernetics. Minneapolis, MN: IEEE, 2004: 2580-2585.

[6] Xiao Y, Seagull JF, Faraj S, Mackenzie CF. Coordination Practices for Patient Safety: Knowledge, Cultural, and Supporting Artifact Requirements. Proceedings of International Ergonomic Association. Seoul, S. Korea: 2003.

[7] Xiao Y, Seagull JF. Emergent CSCW Systems: The Resolution and Bandwidth of Workplaces. International Journal of Medical Informatics 2005; (accepted for publication).

[8] Xiao Y, Gagliano D, Hu P, Mackenzie CF, Alcorta A. Video-Assisted Coordination for Field-Hospital Communication. European Journal of Medical Research 2002; 7(1):94.

[9] Xiao Y, Seagull JF, Hu P, Mackenzie CF, Gilbert TB. Distributed Monitoring and a Video-Based Toolset. Proceedings of IEEE International Conference on Systems, Man, and Cybernetics. IEEE, 2003: 1778-1783.

[10] Xiao Y, Seagull JF, Hu P, Mackenzie CF, deVisser J, Wieringa P. Distributed Monitoring In a Dynamic Environment: Trade-Offs of Information Access and Privacy. IEEE, 2003: 4141-4146.

[11] Kim YJ, Xiao Y, Mackenzie CF. Availibility of Human and Facility Resources in Level I and II Trauma Centers. Journal of Trauma 2005; (manuscript under preparation).

[12] Xiao Y, Kim YJ, Gardner SD, Faraj S, Mackenzie CF. Communication Technology in Trauma Centers: A National Survey. Journal of Emergency Medicine 2005; (accepted for publication).

[13] Plasters C, Seagull JF, Xiao Y. Coordination Challenges in Operating-Room Management: An In-Depth Field Study. Proceedings of the American Medical Informatics Association Symposium. Washington, DC: American Medical Informatics Association, 2003: 524-528.

[14] Seagull JF, Xiao Y, Plasters C. Distributed Planning Over Time and People: Balancing Sampling Effort and Information Accuracy. Proceedings of IEEE International Conference on Systems, Man, and Cybernetics. IEEE, 2003: 1772-1777.

[15] Seagull JF, Plasters C, Xiao Y, Mackenzie CF. Collaborative Management of Complex Coordination Information Systems: Operating Room Schedule

Coordination. Proceedings of Human Factors and Ergonomics Society 47th Annual Meeting. Denver, CO: Human Factors and Ergonomics Society, 2003: 1521-1525.

[16] Moss J, Xiao Y, Zubaidah S. The operating room charge nurse: Coordinator and communicator. 2002: S70-S74.

[17] Moss J, Xiao Y. Improving Operating Room Coordination: Communication Pattern Assessment. Journal of Nursing Administration 2004; 34(2):93-100.

[18] Miller A, Xiao Y. It's About Time: Temporal Rhythms in Large-Scale Coordination Problems. International Journal of Human-Computer Studies 2005; (manuscript under preparation).

[19] Lu YC, Lee JK, Xiao Y, Sears A, Jacko J, Charters K. Why Don't Physicians Use their Personal Digital Assistants? Proceedings of the American Medical Informatics Association. Washington, DC: American Medical Informatics Assocation, 2003: 405-409.

[20] Gardner SD. Understanding Dynamic Capabilities at the Subunit Level: Operational Flexibility and the Crucial Role of Organizational Design and Information Sharing. College Park, MD: University of Maryland Robert H. Smith School of Business Doctoral Dissertation, 2004.

[21] Kim YJ. Time to surgery and outcomes in head trauma patients. Baltimore, Maryland: University of Maryland School of Nursing (Expected), 2006.

[22] Seagull JF, Xiao Y, Plasters C. Information Accuracy and Sampling Effort: A Field Study of Surgical Scheduling Coordination. IEEE Transactions on Systems, Man, and Cybernetics, Part A Systems and Humans 2004; 24(6):764-771.

[23] Xiao Y, Seagull JF, Faraj S. Dynamic Reconfiguring of a Communal Display to Support Rapid Coordination. Journal of Collaborative Computing 2005; (manuscript under preparation).

[24] Xiao Y, Plasters C, Moss J, Faraj S. Transactive Responsibility Systems. British Medical Journal 2005; (manuscript under preparation).