Development of a Research Agenda at the Intersection of Industrial and Systems Engineering and Health Care: Implications for Human Factors and Ergonomics

In September, 2009, AHRQ and NSF convened a workshop in which experts in the fields of industrial and systems engineering (ISyE) and health care explored critical areas of research at the intersection of both fields. The objectives of the project were to (1) articulate a vision for an ideal health care delivery system, (2) determine why current efforts to apply ISyE knowledge to health care have not resulted in meaningful change, and (3) propose a research and action agenda that should be pursued to enable the field of ISyE to substantially contribute to the realization of an ideal health care delivery system. This paper presents the vision of the ideal health care delivery system and elements of the research agenda that are salient to the field of human factors and ergonomics. The ideal health care delivery system was defined as one that is new, patient-centered, and engineered. The research agenda was conceptualized as including topics related to the transfer of existing human factors and ergonomics (HFES) knowledge in health care and to the creation of new HFES knowledge about systems monitoring, modeling, and manipulation.

INTRODUCTION

Over the last several decades, there has been particular interest in applying the tools and techniques of industrial and systems engineering (ISyE) to improve the health care delivery system. Organizations such as the Institute of Medicine and the National Academy of Engineering have made explicit calls to this effect (e.g., Institute of Medicine, 2001; Institute of Medicine & National Academy of Engineering, 2005). However, there has been little uptake of the innovations and improvement strategies advocated in these learned documents. A specific and actionable research agenda on how to achieve change using engineering knowledge is needed by research funding organizations concerned with improving the health of the country. While many engineering disciplines could contribute to the improvement of the health care delivery system, the intent of this initiative was to provide research innovation guidance related to the application of industrial and systems engineering (ISyE), including human factors and ergonomics (HFES), solutions to optimizing the health care delivery system.

Mindful of potential synergies, the Agency for Healthcare Research and Quality (AHRQ) and the National Science Foundation (NSF) partnered on an initiative designed to accomplish three objectives:

1. Articulate a vision for an ideal health care delivery system;

2. Determine why current efforts to apply ISyE knowledge to health care have not resulted in meaningful change; and

3. Propose a research and action agenda that should be pursued to enable the field of ISyE to substantially contribute to the realization of an ideal health care delivery system.

At the core of this initiative was the realization that an ideal health care delivery system will not emerge from only insuring appropriate application of existing ISyE techniques to improve today's health care delivery system. Consequently, this project was specifically targeted toward determining how ISyE could provide the new knowledge needed to achieve breakthrough, as opposed to incremental, change. The topics of study recommended in the research agenda and the initiatives and programs recommended in the action agenda aim to primarily support this push for a fundamentally new health care delivery system. Realizing that such a change may also realistically require smaller-scale efforts, however, the research and action agendas also support the development of initiatives to promote knowledge transfer and the development of ISyE knowledge that will be necessary to sustain the quality of the health care delivery system and to the build capacity of ISyE knowledge applicable to health care.

As detailed below, this project was comprised of three elements: 1) a background report, 2) a workshop, and 3) a final report. Each element of the project was informed by the preceding elements (e.g., the final report was informed by the background report and the workshop). This paper attempts to accurately reflect the deliberations of the workshop participants while simultaneously staying faithful to the knowledge gleaned during the writing of the background report. Specifically, it focuses on presenting the vision of the ideal health care system and the research agenda outcomes that are salient to the human factors and ergonomics audience.

METHODS

The objectives of this initiative were realized by conducting a review of the salient literature and by engaging experts in the fields of ISyE and health care in a critical discussion. A background report containing a summary and critical review of thirteen seminal reports and workshops related to the subject matter of this project was produced and disseminated among identified experts in the two fields (Commission of Systemic Interoperability, 2005; Donaldson & Mohr, 2001; Institute of Medicine, 2000; 2001; 2007; 2008a; 2008b; Institute of Medicine & National Academy of Engineering, 2005; McClellan, McGinnis, Nabel, & Olsen, 2008; National Research Council, 2009; Nelson et al., 2001; Rardin, 2007; Roberts, Uzsoy, Ivy, & Denton, 2008). The purpose of the background report was to provide workshop participants with an overview of the progress that has been made toward achieving the three objectives and to stimulate discussion among participants during the workshop. As such,

the background report was not an exhaustive review of the literature; rather, it contained both a presentation and critique of literature that had made significant contributions to discourse at the intersection of ISyE and health care. Analysis of background materials led to the formulation of purpose statements for the workshop, guided participant invitations, and helped shape the activities undertaken as part of the workshop and afterwards.

During a two-day workshop held on September, 21st-22nd, 2009, in Washington, DC, approximately 40 experts engaged in intense reflection and discussion about the three objectives. Representatives from the sponsoring agencies and the authors of this paper jointly identified workshop participants. Care was taken to ensure that workshop participants included individuals from both academia and industry and individuals at varying stages of the career trajectory. Furthermore, a strong emphasis was placed on inviting individuals who were both embedded in and new to the discourse of improving the health care delivery system.

The goal of the workshop was accomplished through a combination of formal presentations and both large and small group discussions. During a total of nine presentations, the workshop chair, Dr. Patricia Flatley Brennan, and eight invited speakers proposed a vision for an ideal health care delivery system. The two keynote speakers, Dr. Maulik Joshi (President, Health Research & Educational Trust and Senior Vice President of Research, American Hospital Association) and Mr. Aneesh Chopra (United States Chief Technology Officer) provided broad visions for the ideal health care delivery system of the future. The remaining six speakers provided visions that were grounded in six areas of industrial and engineering expertise: 1) finance and quantitative decision-making, 2) information technology, 3) systems analysis, change, and implementation theory, 4) materials management and production processes, 5) human factors and sociotechnical systems, and 6) quality engineering. Stephanie Guerlain (Associate Professor, University of Virginia) provided a vision grounded in human factors and sociotechnical systems.

Large group discussions were used for two purposes: (1) to reflect, as a group, on the information presented by a speaker, and (2) to report out conclusions reached during the small group discussions. These discussions allowed workshop participants to question, clarify, or add to the material presented and to remain engaged in the entire scope of the workshop discussion. The large group discussions were also instrumental in identifying points of consensus and tension between workshop participants.

Small group discussions were used to probe deeply into how specific ISyE specialties could address health care challenges. Five ISyE groups (reflecting the 6 areas above) and six health care area groups (i.e., managing accurate illness and disease; creating effective models of health promotion and disease prevention; insuring chronic disease management; enhancing end-of-life experience; facilitating public health; accelerating discovery) were constructed. Each participant was assigned to one ISyE group and one health care challenge area group. Participants were assigned to work with a different set of individuals for each group to stimulate breakthrough ideas.

A final report synthesizing the contributions of the background report and workshop will be presented to AHRQ and NSF. To ensure that both small and large group interactions were productive and captured for development of the final report, large group discussions were audio recorded. Furthermore, all discussions were captured by a professional note taker and all small group discussions were professionally facilitated.

RESULTS

Vision

Results from the background report and workshop informed the formulation of a vision that departs from current realities and defines characteristics of an ideal system that is *new*, *patient-centered*, and *engineered*: (1) The new, redesigned system is integrated, ubiquitous, distributed, responsive, expansive, flexible, and resilient. (2) Delivery of health care is personalized, facilitated by secure information flow, and mindful of patient privacy. Transparency and open access enable people to make informed choices about their health, with a focus on prevention and health promotion. (3) The delivery system is information-optimized and runs smoothly, efficiently, and safely. All stakeholders leverage ISyE knowledge and information and communications technologies to drive both local and system-wide improvements. Incentives are aligned to enhance quality of life for all, at the individual and population levels. Evidence-based analytics and mathematical modeling inform standardized care processes and biomedical knowledge discovery.

Challenges to Creating a Research Agenda

Two primary challenges were encountered during the process of articulating the research agenda focused on new ISyE methods. Perhaps the most significant challenge encountered in creating the research agenda was defining the boundaries of the ISyE discipline. By its very nature, ISyE is multidisciplinary, drawing on traditions as diverse as psychology and organizational behavior (human factors) and mathematics and computer science (operations research). As the application areas of ISyE have expanded, so too have the traditions on which ISyE knowledge and solutions have been based.

During the workshop, the content proposed for the ISyE research agenda often overlapped with content that would be more appropriate for a public policy, business, law, medicine, computer science, psychology, public health, or urban planning research agenda. For example, participants offered research agenda content related to creating incentive structures and tax policies (overlap with public policy and business) and designing better nutrition and screening programs (overlap with public health). Although it was determined that the discipline of ISyE could make research contributions to the issues noted above, content that was determined to be more strongly within the purview of another discipline was excluded from the research agenda.

The second challenge was workshop participants' belief in the adequacy of current ISyE knowledge. The original

intent of this project was to solely provide a research agenda related to new ISyE knowledge that should be developed to facilitate the realization of an ideal health care delivery system. This original intent was based upon an understanding that current ISyE knowledge suffers from limitations that prevent its application from resulting in breakthrough change. The reasons for which current ISyE knowledge is limited were detailed in the background report that was disseminated to all workshop participants and was emphasized by the workshop chair, Dr. Patricia Brennan, throughout the two-day event.

Despite this attempt to push thinking forward and focus on expanding ISyE knowledge, many participants remained focused on the perceived value of current ISyE knowledge, particularly ISyE knowledge related to their specific research interests. Although new research directions were generated, significant portions of the discussion focused on issues of knowledge transfer and bridging the know-do gap. The reason for this focus is unclear. It may have been that participants did not have an opportunity to read the background report, and, therefore, did not realize the focus of the workshop until later. It may have been that participants wanted to push their own agendas forward. Or it may have been that participants believed in the potential of current ISyE tools to create real change.

Research Agenda

The research agenda provides guidance related to the prioritization of research at the intersection of ISyE and health care to realize the vision of an ideal health care delivery system. This research agenda is intended to be completed in the next five to seven years to yield change in the next ten to fifteen years. Originally, the research agenda was envisioned as only containing content related to the creation of new ISyE knowledge. However, during the workshop, many participants opined that current ISyE knowledge has the potential of producing meaningful change when used pervasively and in conjunction with new knowledge. Consequently, the research agenda presented here provides guidance on investigation required to (1) achieve effective knowledge transfer of existing ISyE knowledge within health care and, more importantly, and to (2) discover and develop new ISyE knowledge particularly germane to achieving the vision of an ideal health care delivery system.

The research agenda is divided along the lines of knowledge transfer and new knowledge creation. The new knowledge directions are presented under three topic areas: system monitoring, system modeling, and system manipulation. Whereas research related to knowledge transfer will expedite the use of effective existing ISyE knowledge, research related to new knowledge creation will lead to the creation of new tools, techniques and methods that may be used to realize the vision of an ideal health care delivery system. In this research agenda, greater emphasis is placed upon the development of new knowledge, because it is believed that better, long-term value will be gained by investing in innovation rather than by spreading existing knowledge.

To aid agencies and researchers in utilizing the research agenda effectively, an additional categorization of the agenda items is offered:

> **Breakthrough:** These items are essential to realizing the vision of the new health care system
>
> **Sustainability:** These items are likely to have benefit and improve the health care system, but will not lead to breakthrough changes
>
> **Capacity building:** These items are necessary to expand the breadth and depth of ISyE knowledge relevant to health care

These categories are conceptualized as complementary, and all are likely to be necessary to achieve and sustain the vision of an ideal health care delivery system. Table 1 and Table 2 present those elements of the knowledge transfer research agenda and new knowledge research agenda, respectively, that are germane to the field of human factors and ergonomics.

Knowledge Transfer Research Agenda	**Category**
• Identification of best practices for use of ISyE knowledge.	Sustainability
• Identification of best practices for dissemination and adoption of ISyE knowledge.	Capacity building
• Identification of best practices for spreading new ISyE knowledge between research and industry and within industry.	Capacity building

Table 1. Knowledge transfer research agenda

New Knowledge Research Agenda	**Category**
1.1 System monitoring: Data collection	
• Consumer-facing health IT solutions that allow patients to self-report their observations, that track and report on trends, and that interact with providers' annotations.	Breakthrough
• Efficient and pervasive methods of data capture.	Sustainability
• New automatic data collection technologies to capture observations from patients and their environments.	Sustainability
• Theories and methods beyond natural language processing for the translation of layperson language into structured computable data.	Sustainability

1.2 System monitoring: Integration	
• Efficient methods for integrating large amounts of data from disparate sources.	Sustainability
• Adequate integration of data collection into workflows in manners that ensure data validity while minimizing interference with clinical workflows.	Sustainability
• Efficient means of integrating information generated from different perspectives and roles (e.g., different providers, patients, administrators).	Sustainability
1.3 System monitoring: Characterization	
• Methods to operationalize contextual knowledge to understand generalizability of data.	Breakthrough
• Methods to characterize how the outcomes relate to the processes.	Sustainability
• Methods to characterize processes, inputs, and outcomes	Capacity building
1.4 System monitoring: Presentation	
• Methods to effectively collect and share data in real-time to foster situational awareness of all individuals involved in patient care.	Breakthrough
• Methods to collect and present information that is valuable to diverse stakeholders such as patients, nurses, primary care and specialty physicians, pharmacists, and social workers.	Capacity building
• Theories and methods for the translation of numerical, analytical, and computational results into understandable and actionable information that multiple stakeholders (e.g., nurses, primary care and specialty care physicians, pharmacists) and lay people can seamlessly retrieve to ensure the human monitoring of the system.	Capacity building
2.1 System modeling: Descriptive models	
• Frameworks that explore the integration of many care sources in the production and delivery of care services, and the coordination among these sources (e.g., end of life care).	Breakthrough
• Methods to model systems as set of flows and processes, not just sets of components.	Breakthrough
• Models that explore the effective use and allocation of different vehicles of health care delivery (e.g., focused factories versus integration, such as Mayo Clinics and Kaiser Permanente).	Breakthrough
• Models of trust between patients, providers, and technology.	Sustainability
2.2 System modeling: Predictive models	
• Models to evaluate entire systems and large-scale system changes before they are implemented.	Breakthrough
2.3 System modeling: Prescriptive models	
• Models of collaboration and competition among health care stakeholders.	Breakthrough
• Models that consider how health IT can be integrated into decision-making processes, how evidence-based knowledge can be integrated into practice.	Breakthrough
• Models that appropriately consider the conflicting objectives of multiple stakeholders and make system-optimal recommendations.	Sustainability
• Models that provide guidance about when either standardization or customization is necessary.	Sustainability
• Models to explore the role and consequences of automation, and providing guidance about what can be fully, partially, or not at all automated.	Capacity building
2.4 System modeling: Models that can handle inconvenient realities	
• Models that can integrate qualitative and contextual knowledge (e.g., culture, ethics, law, psychology, social networks, and politics) and be responsive to changes in it.	Breakthrough
• Methods to model the dynamics between micro-changes and macro-changes (e.g. multi-level ergonomics)	Sustainability
3.1 System manipulation: Translational research	
• Translational ISyE research in health IT design, to develop and incorporate tailored human factors, mathematical modeling, and quality engineering solutions.	Sustainability
• Improving translation from mathematical and technical languages into lay person terminology.	Sustainability
• Improving lay people's understanding of analytical results by developing enhanced data visualization techniques.	Capacity building
3.2 System manipulation: Top-down decomposition	
• Exploring payment structures that accommodate technologically mediated interventions (e.g., text messaging, email, visits by teleconference, etc.).	Breakthrough
• Testing of change and implementation theories, and exploration of the tension between pushing for the application of existing knowledge and trying to develop more usable new knowledge.	Sustainability
• Determining the benefits, limitations, and appropriate use of national, regional, and institutional forcing	Capacity building

functions within the health care setting.	
3.3 System manipulation: Bottom-up integration	
• Determining appropriate approaches to stimulating system-wide change, exploring ways to coordinate between bottom-up integration and top-down decomposition.	Breakthrough
• Exploring how social network theories can be used to trigger and facilitate culture change.	Sustainability
• Determining the role of culture as a necessary element of health care improvement, including the national political conversation and at the level of the patient and provider.	Capacity building

Table 2. New knowledge research agenda

DISCUSSION

It is clear that the current health care delivery system is suboptimal. Lack of efficiency and effectiveness of the system has resulted in health care that is high in cost but not consistently high in quality. Continued use of such a health care delivery system is unwise, particularly given the unprecedented financial distress being experienced by the country.

The field of HFES has already made significant contributions to improving the health care delivery system, particularly in areas of patient safety and health IT design. This research agenda seeks to build upon this work by providing direction for HFES research that moves beyond efforts to implement incremental improvement or optimization of one aspect of the health care delivery system (e.g., decreased number of wrong site surgeries, improvement in health IT user interfaces).

Specifically, this research agenda seeks to identify and encourage HFES research likely to stimulate breakthrough change in the areas of system monitoring, modeling, and manipulation. Examples of research areas necessary for realization of such breakthrough change include: 1) determining how to effectively collect and share data in real-time to foster situational awareness of all individuals involved in patient care and 2) determining how models can integrate and be responsive to qualitative and contextual knowledge. In addition, HFES research in the categories of sustainability and capacity-building is simultaneously needed to foster continued improvement of the current and future health care delivery systems.

Industrial and systems engineering professionals, including human factors and ergonomic professionals, and health care professionals should work together and team with other stakeholders to accomplish the research agenda outlined in this report. By solidifying the partnership with health care and by focusing on the development of new tools, techniques, and methods, and how health IT may facilitate development and use of this new knowledge, the field of industrial and systems engineering, including human factors and ergonomics, can help realize the vision of an ideal health care delivery system.

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NOTES

This paper represents a small part of a larger federal report that will be submitted to AHRQ and NSF and that is scheduled for publication this year. The larger report includes a more comprehensive research agenda, an action agenda, as well as a discussion of the barriers and facilitators to realizing change through the use of ISyE knowledge. The parts chosen for dissemination to HFES represent the aspects of the research agenda that were deemed to be most salient to the discipline.

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