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Health Care Research That Delivers: Introduction to the Special Issue on Cognitive Factors in Health Care

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Research that addresses human factors issues in health care has made good progress since the landmark 1999 Institute of Medicine report on medical error (Kohn, Corrigan, & Donaldson, 1999), yet patient safety remains a persistent challenge for the health care system. While this challenge reflects many factors, we focus on the need for research that is sufficiently comprehensive to identify threats to patient safety, yet specific enough to explain how provider and patient factors interact with task and health context to engender these threats. Such research should be theory-based, yet also problem-driven; exert experimental control over theoretically relevant variables, yet also involve participants, tasks, and contexts that represent the problems of interest. A tension exists between theory-based, experimentally controlled research on the one hand, and problem-driven research with representative situations on the other. The studies in this special issue are both informed by theory and guided by application, reflecting what Stokes (1997) referred to as "use-inspired basic research." Collectively, these studies represent progress toward improving patient safety and the quality of health care. However, important work remains to be done to significantly improve health care by more comprehensively managing tensions between theory and application and different research methodologies. We discuss barriers to accomplishing such research in general (the challenge of testing theory in situ in rich environments), and specifically in the health care domain. Significant progress will require research programs that thoughtfully manage mixed methods across a series of converging studies.

Keywords: health care, cognition, patient safety, medical error, use-inspired basic research

The landmark 1999 Institute of Medicine (IOM) report identified preventable adverse events as a significant patient safety issue for the national health care system (Kohn, Corrigan, & Donaldson, 1999). It also emphasized the potential of human factors methods and theories for addressing this issue, for example by explaining how medical errors arise and how they might be mitigated. The report quantified the number of people who died from preventable medical errors in terms of crashes of jumbo jets: Deaths from preventable adverse events in the U.S. were equivalent to a 727 or two crashing everyday of the year.

Despite recent advances in human factors and human performance research related to health care (e.g., Carayon, 2007; Flin, O'Connor, & Crichton, 2008), preventable adverse events and medical errors remain a significant challenge to the health care system (Landrigan et al., 2010). These problems are likely to increase in the future, for several reasons: 1) An increasingly aging society means there will be more older adult patients with chronic illnesses requiring complex care in both inpatient and outpatient settings (Charness & Boot, 2009); 2) The Patient Protection and Affordable Care Act (2010) will likely result in more patients with more diverse health care needs and abilities entering the health care system; 3) Increasing adoption of health information technology, although intended to increase safety and reduce cost, may also increase the complexity of delivering health care services if not introduced in ways that are consistent with clinicians' and patients' goals, abilities, needs, and practices (e.g., ONC, 2011; Stead & Linn, 2009).

Finally, an important set of factors relates to the lack of evidence-based practices that support robust clinical care, or the limited adoption of those practices that do exist (Landrigan et al., 2010). This in turn reflects a paucity of research sufficiently comprehensive to identify threats to patient safety yet also specific enough to identify how provider and patient factors interact with task and health context to engender these threats.

Toward Effective Health Care Research

A research program that would help develop evidence-based practices and guide adoption of existing practices from fields with similar safety challenges (e.g., aviation) should have (at least) the following characteristics:

a. Problem-driven. The research must address critical challenges to patient safety, and to the effectiveness of health care more broadly. For example, adverse drug events and surgical errors are frequent threats to safety in inpatient settings (Kohn et al., 1999; Landrigan et al., 2010). Adverse drug events are also common in the home, and our aging population makes self-management of chronic care in these settings even more important (Aspden, Wol-

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cott, Bootman, & Croenwett, 2007). To the extent problem-driven studies specify critical contextual features (e.g., task, environment), their findings are more likely to apply directly to improving health care; for example, by addressing issues related to implementation of solutions in clinical contexts.

b. Theory-guided. Problem-based research will be more successful when guided by theories that identify critical facets of the problem as they relate to characteristics of practitioners (e.g., skills, knowledge, abilities, and other characteristics), tasks, and environments. Theories of health care processes and outcomes vary in scope, some address relatively narrowly defined processes such as nurse interaction with medical devices, whereas others encompass multiple levels of health care as a complex social system (Durso & Drews, 2010). Just as problem-based research is more successful when guided by theories, theories will more likely advance when tested against constraints of actual problems.

c. Experimental control. Empirical methods are essential for identifying problem features, as well as for evaluating theories of the processes that give rise to these problems and the solutions that address them. Experimental control of theoretically defined variables supports causal inferences about the processes underlying performance. Experimental designs often involve orthogonal manipulation of a small set of variables with random assignment of participants to the resulting conditions, which is often most feasible in relatively simple and abstract laboratory settings. For example, a small set of medical device interfaces that vary along theoretically defined dimensions (arrangement of controls, depth of menu options, etc.) can be developed and participants randomly assigned to the interface conditions (e.g., Lin, Vicente, & Doyle, 2001).

d. Representativeness. Participants, tasks, and contexts must be chosen to represent the phenomena of interest. While participants are often sampled so as to generalize beyond the study sample, this is less often the case for tasks and the environments in which the tasks are embedded (Brunswik, 1955). Yet, both approaches to sampling are important for developing representative situations and producing findings that can generalize to the target phenomena. Representative situations in turn depend on a theoretical understanding of the key features of the target environment. Therefore, such studies will have a broader impact on health care because they are grounded in a careful analysis of the critical features of the target phenomena; otherwise, findings will likely extend only to a specific task or context (Brunswik, 1955). An example of a study with a representative situation would measure performance of experienced practitioners such as nurses (and perhaps the processes underlying performance) as they accomplish typical tasks in situ, and perhaps compare performance across naturally occurring task conditions such as different types of interruptions (e.g., Grundgeiger, Sanderson, MacDougal, & Venkatesh, 2010).

Another aspect of generalizability rests on the inferential statistical techniques that allow the research to generalize from the specific sample of participants (and tasks) in the study to the target population. A challenge for designing studies with representative situations is to obtain sufficient numbers of practitioners (e.g., nurses, physicians) and critical events (e.g., adverse drug events) in order to achieve statistical power.

As any psychologist recognizes, there are both correlations and tensions among the four features of effective research described above. For example, theory-driven research is often accomplished through studies with rigid experimental control, but is implemented in simple contexts that can have the effect of limiting representativeness. Moreover, statistical power may be boosted by the use of easily obtained participants who have little or no experience on the tasks under investigation. Making the leap from the lab to the operational setting may be difficult in such studies. On the other hand, problem-driven scientific studies are often high in representativeness, making it clear how the findings might be relevant in the health care situation. However, such work often simply cannot control all the important variables, thus limiting the internal validity of the work, and producing outcomes less likely to feedback to theory. Statistical power may also suffer because experienced practitioner participants, who are often essential for achieving representativeness, can also be difficult to recruit, resulting in small samples. In short, theory-driven tends to contrast with problem-driven, as does experimental control with representativeness. The theory-driven and controlled cluster leans toward what most people think of as basic research, while the problem-driven and representative cluster often characterizes what might be thought of as applied research.

The studies reported in the current volume are remarkable in that they are all both informed by theory and aimed at application. Stokes (1997) addressed the tension between the role of theory and application in research, and referred to the productive interplay between theory and practice as use-inspired basic research. As Stokes put it, research can be motivated by a quest for fundamental understanding or a consideration of use. When motivated by both, the work resembles the efforts of Louis Pasteur, who moved nimbly and purposefully between basic and applied research. Patient safety may be most effectively advanced by research in "Pasteur's quadrant," where theoretical breakthroughs (such as theory of fermentation processes) occur when addressing practical problems such as food spoilage, in contrast to research driven by purely theoretical aims or application.

Figure 1 captures the interplay between Stokes' dimensions. All four quadrants exist in health care. Valuable work occurs in health care even when health care workers are not motivated either by theoretical implications or broad applications. Stokes toyed with naming this "low understanding/low use" quadrant after Roger Peterson (of field guide fame), but we characterize work in this cell as the type of research that is very context-specific. For example, a group of dedicated and concerned nurses may collect data in their particular hospital to better understand what is causing the backlog in patient flow through their chemo department. They may solve the problem in their hospital for the good of both staff and patients, but they are not particularly concerned with nor motivated by theoretical concepts at play nor are they particularly motivated to broadly apply the solution to other hospitals. The absence of theory-based analysis of the problem and its causes likely guarantees that the solution will apply to the specific problem at hand but not to other contexts of use. Perhaps the reader may not view work in this quadrant as research, but indeed many of the advances that are actually implemented in a hospital are from exactly this kind of ad hoc work that is driven by that hospital's particular problems.

When research is motivated exclusively by fundamental understanding, with little concern given to consideration of use, the researcher is in Bohr's quadrant. The cognitive psychologist who conducts work on the nuances of visual search in laboratory tasks would be classified as falling into this quadrant, as would the researcher who seeks funding by pointing out how such work may

		Consideration of Use	
		Low (Narrow)	High (Broad)
Quest for fundamental understanding	High	Bohr's quadrant A basic researcher explores subtle parameters of a psychological process, perhaps noting how it may be "applicable" to health care	Pasteur's quadrant A researcher designs a study based on theory and aimed at an applied problem of immediate concern to patient safety
	Low	Peterson's quadrant Group of concerned health care workers solve a problem specific to their hospital	Edison's quadrant A researcher designs a study for nontheoretical reasons (perhaps by speculating on an approach or importing one from another domain) aimed at a problem of broad concern (e.g., patient hand-offs at shift change).

Figure 1. Stokes' research taxonomy, as applied to health care research (adapted from Stokes, 1997, Figures 3–5).

someday be "applicable" to surgery, but admits it is far from immediate application.

Researchers in Edison's quadrant, on the other hand, are motivated only by broad application. Although their work certainly taps underlying scientific principles, like Edison these researchers do not use theory to motivate their experiments and are not concerned with the theoretical implications their discoveries may have. In health care, there are efforts to improve health care by importing procedures from other disciplines without considering the theoretical differences between health care and the operational domain in which the procedure is currently used. An example might be the use of the readback procedure borrowed from aviation (in which pilots receiving radio messages from Air Traffic Control repeat the key information so that the controller can confirm that the message has been understood) to improve communication between clinicians at shift change. The success of such insertions are often tested, then abandoned, another tested, modified, and so on. To Edison, such brute force efforts were commonplace and not failures but steps forward, albeit atheoretical ones.

Special Issue Focus

The papers in this special issue, *Cognitive Factors in Health Care,* all describe studies that are both theoretically guided and address critical problems of broad significance for health care, thus falling in Pasteur's Quadrant (Stokes, 1997). Consistent with the aims of this journal, each study is a theoretically guided investigation of an applied problem. By managing the tension between theory and application, the studies identify the important problems of patient safety as well as the contextual and practitioner factors that contribute to these problems, and help develop solutions that address them. Collectively the studies address a wide range of important patient safety problems such as provider error in inpatient settings related to diagnosis, medication administration, and surgery, as well as patient-related problems in outpatient settings, such as comprehension and decision-making related to illness prevention and self-care.

The papers tend to fall into two groups in terms of how they balance theory and application. Four of the papers (DeLucia & Griswold; Garcia-Retamero & Cokley; Kalatunga-Moruzi et al.; Rawson et al.) use experimental designs with orthogonal manipulation of variables in order to draw conclusions about causal relationships underlying performance. The participants in these studies, while not health care practitioners or patients, are in sufficient numbers to give the studies statistical properties not found in studies with only a few participants. These studies capitalize on experimental control to inform theoretical accounts of cognitive and perceptual mechanisms underlying clinician or patient performance, in part by focusing on individual performance within simplified laboratory environments that simulate critical properties of the target health care contexts.

The other three papers investigate performance in study contexts that involve practitioners (nurses or physicians) performing authentic tasks in complex simulated (Burtscher et al., Marquard et al.) or actual (Park et al.) environments. The focus of these studies is more global, capturing levels of health care systems beyond the performance of individual practitioners. The studies investigate cognitive processes at the team level (Burtscher et al.) or processes underlying individual performance in the context of complex tasks that involve other practitioners, such as surgery (Park et al.) and medication administration (Marquard et al.). A strength of these studies is their use of representative situations that may have direct implications for practice.

Challenges to Health Care Research

Each of the studies in the special issue makes progress toward improving patient safety and the quality of health care. Of course, there remains important work to be done to move research forward so as to significantly improve health care. As far as we know, a single study with all of the features described above—manipulated variables, experimental control, large numbers of representative participants, conducted in a representative environment with an authentic task—does not exist. There are a number of reasons why such studies would be rare.

Some of the impediments would affect any effort to uncover theoretically relevant causal mechanisms in a rich in situ environment, not just efforts in health care. These include problems like that of gaining control in representative environments, recruiting experts in sufficient numbers, manipulating variables when real consequences are at stake, and so on.

Other impediments to achieving all of these features in a research program may be especially likely in the health care domain. Because of the insular culture and other features of the domain, health care is different in fundamental ways from other operational domains that have been the focus of applied experimental psychology. Psychologists have only recently begun to understand the health care system. Most of the research thus far has involved translocating research into the health care domain from other operational domains, like aviation. Researchers successful in a structured, engineered domain such as aviation face challenges when investigating health care; what Durso and Drews (2010)

have argued is a socionatural system. Readers familiar with research into ecosystems will recognize the complexities involved in studying natural systems, and most of us recognize the risks involved in imposing interventions to natural ecosystems.

The goal of combining all of the features of research that we have discussed may not (and perhaps should not) be achieved within a single study, but in a program of research, a series of studies, each exemplifying different characteristics with converging, mutually constraining findings. The theory driving this work would balance comprehensiveness (as exemplified by system theories that describe the web of factors underlying error in complex domains such as health care; Durso & Drews, 2010; Vicente & Christoffersen, 2006) with specificity (as exemplified by theories that address cognitive processes underlying particular types of errors). Much of the work that analyzes cognitive processes has been most successful at the microlevel, where problems are more amenable to experimental control and precise measurement (such as the interaction of practitioner cognition and medical device design; for examples see Morrow, North, & Wickens, 2006; or the impact of interruption on practitioner performance; Grundgeiger et al., 2010) than at meso and macro levels of health care systems (distributed teams; lack of "vertical integration" across levels of system that may contribute to large scale accidents; Durso & Drews, 2010; Vicente & Christoffersen, 2006). The studies in this special issue also tend to focus on cognitive processes underlying individual performance (and to a lesser extent how these processes interact with perceptual-motor and social factors). Future work should focus on a broader range of practitioner factors (physical and emotional as well as cognitive) and how they interact with health care contexts to promote or undermine effective health care.

Conclusion

We believe that health care research is in need of more work in Pasteur's quadrant. Further, we believe that the work in that quadrant needs to be coordinated from the outset so that there is better management of mixed methods; that is, the coordination of different study designs (e.g., experimental, quasi-experimental, field), measures (e.g., observation, survey, response latency and accuracy, process tracing techniques), and analytical tools (task analysis, computational modeling) in terms of theoretical and practical goals. If a single study cannot capture, and in some cases should not capture, all of the features that may be important in answering a research question, then instead programs of research that integrate many types of methodologies must be conducted. How might we move in this direction? Individual researchers may take it upon themselves to master a variety of methodologies and to use the strengths of the methodologies in order to complement one another. After a naturalistic observation, and then a field study with some efforts to control variables, the researcher might go to the lab to test directly a suspected causal factor. In fact, this is often how Pasteur worked. Alternatively, individual researchers may seek out others to form consortia that bring together researchers whose motivations and skill sets complement one another. However, in the spirit of the 1999 IOM report's focus on patient safety as a national priority (Kohn et al., 1999), such grassroots efforts on the part of dedicated scientists and health care practitioners would benefit from policy changes from government and private funding agencies that would facilitate the integration of methodologies and motivate changes in the management of mixed methods.

The papers in the present special issue represent impressive attempts to integrate the strengths of multiple research features to address patient safety and other facets of health care. As such, they reflect encouraging progress toward the kind of comprehensive research that is needed to inform both use and fundamental understanding in the field of health care.

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