UCSF
UC San Francisco Previously Published Works

Title
Characterizing a Naturalistic Decision-Making Phenomenon

Permalink
https://escholarship.org/uc/item/5gp6z7kb

Journal
Journal of Cognitive Engineering and Decision Making, 10(3)

ISSN
1555-3434

Authors
Patterson, Emily S
Militello, Laura G
Su, George
et al.

Publication Date
2016-09-01

DOI
10.1177/1555343416652524

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Author Manuscript

HHS Public Access
Author manuscript
J Cogn Eng Decis Mak. Author manuscript; available in PMC 2017 September 01.

Published in final edited form as:
J Cogn Eng Decis Mak. 2016 September ; 10(3): 229–243. doi:10.1177/1555343416652524.

Characterizing a Naturalistic Decision Making Phenomenon: Loss of System Resilience Associated with Implementation of New Technology

Emily S. Patterson,
Ohio State University, Division of Health Information Management and Systems, School of Health and Rehabilitation Sciences, Columbus, OH, USA, 614 292 4623

Laura G. Militello,
Applied Decision Science, 117 Chatham Dr., Kettering, OH, USA 45429, (937) 602-7844

George Su, and
University of California San Francisco School of Medicine, Medicine, San Francisco, CA, USA, 415 206 8314

Urmimala Sarkar
University of California San Francisco School of Medicine, Medicine, San Francisco, CA, USA, 415-206-4273

Abstract

We describe a phenomenon viewed through the conceptual lens of a naturalistic decision making perspective: a loss of system resilience, due to increased difficulty in performing macrocognition functions, associated with the implementation of new information technology. Examples of the phenomenon collected in a targeted literature review are characterized by stakeholder groups, technology, typical changes in workflow before and after implementation, and potential impacts on macrocognition and patient outcomes for four clinical care environments. The loss of system resilience is due to increased difficulty in performing macrocognition functions: 1) sensemaking due to less effective cognitive warm-up and collaborative framing strategies, 2) detecting events due to missing trends in data and changes to orders, and 3) coordinating due to less clinical knowledge during scheduling and updating information, and less effective cross-checks. Potential impacts to patient safety include an increase in unnecessary care, missed care, delays in diagnoses and treatment, redundant care, inaccurate diagnoses, medication errors, and adverse events. We recommended future conceptually-driven research in other complex, sociotechnical settings order to develop useful metrics and reduce the risk of incurring undesirable and unnecessary impacts on cognitive work associated with new technology.

Corresponding author names and contact details: Patterson, Emily S., Address: 543 Atwell Hall (HIMS), 453 W 10th Ave, Columbus, OH 43210, Phone: 614 292 4623, patterson.150@osu.edu.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

INTRODUCTION

As many have pointed out, the theoretical lens which is used to view the messy, complex naturalistic world of work shapes the phenomena which are discovered during ethnographic observational studies. In Naturalistic Decision Making (NDM), the theoretical perspectives have emphasized how expert practitioners perform cognitively complex functions in demanding, real-world situations characterized by uncertainty, high stakes, team and organizational constraints. (Klein, 2008) In resilience engineering, experts augment the system's resilience by going beyond assigned tasks and roles and by reserving resources (adaptive capacity) to deal with surprise (Hollnagel, Woods, & Leveson, 2007). In addition, the Stress-Strain model of resilience depicts how much systems can be stretched before they are strained beyond their capacity; when this occurs, the system is brittle in that it is vulnerable to being compromised, as defined by experiencing a loss in capability in the face of unanticipated situations (Woods & Wreathall, 2008). In this paper, we augment these existing foundations by providing a theoretical definition of a phenomenon that is easy to overlook: loss of system resilience associated with the implementation of a new technology due to increased difficulty in performing macrocognition functions. We expect that both gains and losses are typically encountered following implementation of a new technology due to changes in roles, workflows, and performance expectations, but we restrict our focus to loss in order to make theoretical progress on characterizing a phenomenon that can aid proactive mitigation of negative unintended consequences. Similarly, individuals can increase system resilience by employing workload management strategies or improving expertise, but we restrict our focus to system resilience, where the system is a joint cognitive system (JCS) composed of multiple experts aided by sophisticated technological artifacts. We provide a number of related examples of this phenomenon grouped by clinical care setting. The examples were collected during a targeted literature review of known articles and articles that cited seminal articles (Patterson, Cook & Render, 2002; Koppel et al., 2005) on unintended consequences from the introduction of new technology. We discuss how an increased difficulty in performing macrocognition functions could potentially adversely impact traditional patient safety measures.

In prior NDM research, we identified five functions in macrocognition: detecting problems, sensemaking, re-planning, deciding, and coordinating. Detecting problems is noticing that events may be taking an unexpected direction. Whether positive or negative with respect to goal accomplishment, change requires explanation and might signal a need or opportunity to reframe how a situation is conceptualized (sensemaking) and/or revise ongoing plans (re-planning). Deciding is far more complex than classical discussions of decision-making (Hoffman & Yates 2005); a central aspect is modifying current levels of commitment to related actions (courses of action) and nominal options (defaults) based upon accommodating different stances of stakeholders by making trade-offs. Coordinating is managing interdependencies of activity and communication across individuals acting in roles that have interacting goals (Patterson & Hoffman, 2012).

In contrast to the NDM perspective which emphasizes the human role, healthcare informatics tends to emphasize the role of new information technology in enhancing patient safety. For example, a predominant theoretical framework in health informatics is the Scurve for adoption, where a technological innovation is used by early adopters, a critical mass quickly, and then late adopters. With this framework, there is little description of how technology is modified or tailored by the 'sharp end' practitioners or what happens to 'leftover' tasks which are not performed by the information technology. Another predominant theme in informatics is that 'sharp end' practitioners show 'creativity' in 'employing workarounds.' Workarounds are viewed to defeat the intended purpose of the system-as-designed in order to increase efficiency at the cost of negative unintended consequences on safety.

With NDM, a primary contrasting theoretical framework is that expert practitioners 'mind the gap', specifically by adapting technology, policies, and resources in order to enhance resilience. Resilience is defined as "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances so that it can sustain required operations, even after a major mishap or in the presence of continues stress." (Nemeth et al., 2008) This notion of resilience is the flip side of 'work to rule' strikes, where practitioners mindlessly follow standard operating procedures with a 'learned helplessness' perspective. 'Work to rule' strikes are typically conducted with the intent of demonstrating how systems are over-constrained by multiple, somewhat overlapping requirements and social norms which are documented principally in policies and procedures, as well as implemented in technological supporting artifacts (Vicente, 1999).

In this paper, we build upon the theoretical foundations of resilience from the NDM perspective to describe a phenomenon of loss of resilience associated with the implementation of new health information technology (HIT) in clinical settings. Although we and others have documented negative unintended consequences to patient safety from the introduction of electronic medication administration (e-MAR) (Patterson, Cook & Render, 2002) for nurses and electronic health records (EHRs) for physicians (Koppel et al., 2005) and nurses (Gephart, Carrington, & Finley, 2015), this phenomenon is distinct from prior contributions. Instead of design flaws, high false alarm rates, high rates of interruptions, or difficulty in observing 'black box' actions taken by automated HIT functions, the contribution of this paper is in characterizing and providing examples of a phenomenon of new technology making macrocognition functions more challenging to perform, thus resulting in the potential for increases in standard patient safety outcome measures such as delays to diagnosis.

DESCRIPTION AND EXAMPLES OF LOSS OF RESILIENCE FOLLOWING HIT IMPLEMENTATION

We describe a phenomenon viewed through the conceptual lens of a naturalistic decision making perspective: a loss of system resilience, due to increased difficulty in performing macrocognition functions, associated with the implementation of new information technology. In this section, we provide all known published examples of this phenomenon in healthcare (many of which were not described in this way in the publications), grouped exclusively by four clinical care settings: 1) outpatient care, 2) inpatient care, 3) transitions from inpatient to outpatient care, and 4) emergency care.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

First, Table 1 summarizes examples in the context of ambulatory care. The first includes observations about how EHRs have changed the nature of documentation and the ways in which documentation are used. Prior to the introduction of EHRs, it was common for primary care and specialty care providers to document noteworthy aspects of care (Hirschtick 2012). This provided a quick, prioritized summary that could be reviewed prior to a scheduled visit, typically one day to a week in advance, with the patient. EHRs have facilitated remote access to data without having to coordinate with others accessing the chart and more thorough documentation through the use of templates, and cut and paste features that make it easy to copy information from a prior progress note to a new one (Simpson, 2015). While there are benefits to thorough documentation, one drawback is that there is an increased potential for outdated information (Sockolow et al., 2014) and even data placed in the wrong chart due to cut and paste errors (Lowry et al., 2015). Templates may restrict options, requiring the physician to select the closest option or leave it blank, and resulting in misleading data or missing information. (Patterson et al., 2005) As a result, it is difficult to find the new, relevant, and important information when reviewing progress notes. Perhaps even more concerning, it is less common for clinicians to thoroughly review documentation prior to the patient visit; rather, with the introduction of EHRs a culture shift has emerged in which clinicians are more likely to review one or two progress notes five minutes before the patient arrives or during the scheduled visit with the patient (Lowry et al., 2014). This review still occurs for high-priority or specialty care patients, but less routinely for all patients by physicians, physician assistants, or nurse practitioners unless specialized personnel, such as medical scribes, are employed to support the task. System resilience is reduced in that providers are stretched by needing to put in heightened effort and time to detect what is insightful in a larger set of potentially relevant information. When there are inconsistencies in interpretations, additional effort is expended personally retrieving and reviewing primary data such as images and lab results, in some cases from different systems that require additional log-ins. A compensatory mechanism of relying upon cogent summaries written by trusted colleagues, such as a well-respected consultant, might not be able to be employed in the absence of such a summary or if the summary was done prior to knowing a critically important update. Without the time to adequately review historical data, inaccurate diagnoses, delays in diagnosis, and delays in treatment are more likely to occur.

A second example includes observations about changes in communication strategies with the transition from paper to EHRs. Prior to the introduction of EHRs, it was common for clinicians to receive reminders, high priority information, and summaries as annotations or post-it notes in an organized binder outside the exam room door prior to the scheduled patient visit. Other types of reminders or highlights were received via telephone, fax, or even face-to-face communications between primary care and consulting physicians. As communications have become more “digital,” they have also become more fragmented, in that new media are available (email, messaging via patient portals, communication via the EHR including specialized communications such as ‘jellybeans’, eReferrals), as well as the continuation of prior media (paper faxes, telephone messages, post-it notes from colleagues, mailed written reports and lab results). These varied and fragmented communication media increase the need to be ‘vigilant’ in tracking multiple communication modes and increase the likelihood of missed care, delays in care, and adverse events (Lowry et al., 2015).

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

A third example relates to a reduction in patient involvement in framing a historical narrative of relevant events and what recent events have prompted scheduling a visit. In traditional training about how to have a first visit with a new patient, physicians were encouraged to elicit the story in the patients' own words in order to minimize bias from prior care providers. Following the transition to EHRs, it is typical for no patient-led interviews to be conducted. Instead, providers rely upon the narrative (when available) from a prior progress note to form the skeleton of a newly documented narrative, often initiated prior to the patient entering the room, which is then updated by information obtained in response to queries made. Typically, queries are triggered by structured data elements which are filled in during the visit, including what items are available for selection from existing drop-down menus (Hirschtick 2016). By eliminating the elicitation of an unbiased narrative from the patient, there is a higher risk of inaccurate diagnostic framing, and therefore inaccurate diagnoses or delays to diagnoses.

A fourth and final example includes observations of a shift in time allotment as interacting with the EHR requires more of the clinician's time. Because interacting with the interface to update problem lists takes longer than with the paper chart and it is possible to monitor what personnel actually document the updates, problem lists and associated diagnostic and procedural codes tend to be less accurate and updated. Therefore, some providers will take additional time to 'clean up' this information, and also will benefit less from insights gained by prior specialist care providers who might not agree that it is their responsibility to add problems and codes in their area of practice. In addition, observations suggest that clinicians spend more time with non-clinical tasks such as locking/unlocking notes, accepting revised text for billing purposes, checking patient charts in and out of the EHR, confirming the use of or explaining acceptable deviations from best practice recommendations, selecting and searching for detailing billing-related data (International Classification of Disease codes, Current Procedural Terminology codes), and entering data required for accreditation, licensing, and regulatory purposes (Lowry et al., 2014). As a result, less time is available for reviewing, modifying, and updating problem lists and chief complaint documentation during or immediately following a patient visit. This shift suggests an increased likelihood of inaccurate diagnoses, delay in diagnosis, and delay in treatment.

Table 2 summarizes examples in the context of inpatient care. In inpatient settings, changes in documentation use similar to those in outpatient have been observed. Prior to the introduction of EHRs, it was common for a registered nurse (RN) to frame an initial assessment of a patient based on a short set of handwritten notes that included high-significance information from prior visits. After the introduction of the EHR, RNs are more likely to review some of the comprehensive, systematic, standardized displays only occasionally due to the need to login and navigate to more places and having more documentation information automatically generated. Furthermore, these standardized displays are more likely to contain outdated "copy forward" flowsheet documentation from prior time periods for assessments of the same patient, hidden text in comment fields (Collins et al., 2012), and "copy paste' documentation from the wrong patient than the handwritten notes used previously. This increases the likelihood of missed events, and delays in detection of events for patients with multi-day hospital stays.

Author Manuscript

With regard to managing medications, historically RNs have reminded physicians to renew automatic stop orders when they notice discontinued medications crossed out on a paper medication administration record. However, in the electronic medication administration record (e-MAR), discontinued medications are not displayed except on demand in many systems. Without the visible reminder that the medication was automatically discontinued, missed medications are more likely to occur (TJC, 2008).

With regard to administering medications, RNs traditionally reviewed medication names, dosages, and routes printed medication administration records. In contrast, e-MARS by design encourage RNs to focus on confirming that the scanner displays a green light after scanning a medication barcode rather than reviewing the actual details of the medication order. This shift in focus can increase the likelihood of failing to detect medication errors not related to having the wrong patient (Hunter, 2011). Similarly, resident physicians have switched from reviewing administration times written on paper MARs to confirm that medications were administered as ordered to reviewing medication orders in EHRs that have been verified by pharmacists. Physicians viewing administration times need to login to an additional technology, the e-MAR, which they do not typically use. In addition, disconnects between when barcode medications are scanned, and thus automatically documented, as well as restrictions on easily changing automatically documented times to preserve the integrity of the legal record, have reduced physician trust in the veracity of administration times.

e-MARS have also changed the way in which new medications are viewed and displayed. Prior to the introduction of e-MARS, after new medication orders were verified by pharmacists, they were typically displayed on ‘color wheels’ on the outside of paper-based chart binders, or automatically printed to printers on the hospital unit. With e-MAR technology, RNs login to view new medication orders. With some systems, they must remember to manually refresh the screen to be sure that all new orders are currently displayed (Patterson, Rogers, & Render, 2004). Without notifications ‘pushed’ to the nurse that a new medication order has been ordered and verified, missed medications are more likely to occur.

Strategies for documentation and review have changed for nurses, as well as physicians. Traditionally, RNs in an inpatient setting would review the paper chart in order to generate personal crib notes (colloquially described as ‘brains’) starting 30 minutes before the shift. They would add information during verbal handover, and use the crib notes throughout the shift to plan activities and jot down information. (Pennathur et al., 2013) With the adoption of EHRs, nurses are more likely to arrive at the beginning of the shift and generate personal crib notes based on the verbal handover, and then update the notes by logging in and reviewing the EHR information, as needed. The crib notes are still used to plan activities and jot down information. With the reduced chart review, however, the crib notes are less likely to be complete, increasing the likelihood of missed care or redundant care.

EHRs have also had an influence on nursing handovers. Historically, nurses would provide a report face-to-face or over the phone about a patient or set of patients. The handoff provided a time to ask and answer questions real-time prior to providing care. With the introduction of EHRs, handover documentation via the EHR has increased and verbal handovers have been

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

deemphasized. They are conducted as needed, and might include a review of some patients' written or audio-taped information captured on forms, faxes, and voice-mail (Horwitz et al., 2009) during the early portion of a shift period.

Table 3 includes examples that affect transitions from inpatient to outpatient care. With regard to consultations, prior to the introduction of EHRs, results from tests and consults were received in an organized format, such as a printout with key information highlighted in yellow by a nurse prior to talking with the patient. With the increased ease of digital data transmission, results may appear in multiple "inbox" communications, faxes, mail, voicemail, or computerized alert messages that are not organized, highlighted, or easily viewed immediately prior to a patient visit (Carrington & Effken, 2011). For consultants, often it is difficult to send results to multiple clinicians and interdisciplinary team members. Thus, clinicians are most likely to view those alerts that appear upon login or prior to doing specific actions within the EHRs. One study found that when it is known that alerts are sent to more than one healthcare provider, they are less frequently viewed (Singh et al., 2009). As a result, inaccurate diagnoses, delays in diagnosis, delays in treatment, and missed patient events are more likely.

Another example is related to case management or care coordination by specialized providers, including care coordination, transplant care coordination, and discharge planners. Prior to the introduction of EHRs, it was common for a specialized provider to actively coordinate scheduled inpatient and outpatient care activities, and to facilitate coordination across the care team. Increasingly, patients request or are asked to schedule their visits directly via patient portals (Hogan et al., 2011; Goldzweig et al., 2013). For some patients, particularly those with complex conditions, this can lead to delays in care (because they are scheduled late) or unnecessary appointments (because they are scheduled early). In some situations, these sub-optimal schedules can cause adverse events, such as a possibly irreversible loss of visual acuity when intravitreal injections are not given during the recommended time interval (Patterson et al., 2015).

Table 4 includes an example from emergency care. Prior to the introduction of EHRs, most emergency departments (EDs) used a whiteboard to track the status of patient care. All clinical personnel could anonymously update and view whiteboard information about working diagnosis and assigned providers. The introduction of EHRs made it easier to implement electronic whiteboards (e-whiteboards) by reducing the need for extensive data entry. These large, computer-driven displays require that clerks and other assigned clinical personnel login to view and update information about working diagnoses and assigned providers. For clerks, updating information is typically done after higher-priority tasks such as patient registration in the EHR are completed (Patterson et al., 2010). With EHRs, patient care can often not be provided until the patient is registered in the EHR, and in some cases until a barcoded band is placed on the patient's wrist. The login eliminates anonymity and makes information in this display and views of the display auditable, changing the primary function of the display from an at-a-glance status update to standardized, formal documentation of current and retrospective data.

DISCUSSION

In this paper, we described an apparently novel characterization and provided examples of an NDM phenomenon of a loss of system resilience associated with workflow changes following the implementation of new health information technology used by multiple stakeholder groups. The loss of system resilience is due to increased difficulty in performing macrocognition functions: 1) sensemaking due to less effective cognitive warm-up and collaborative framing strategies, 2) detecting events due to not being able to adequately resolve conflicting information, missing trends in data and changes to orders, and 3) coordinating due to less clinical knowledge during scheduling and updating information, and less effective cross-checks. 3) Although this loss is somewhat predictable when technology automates a subset of activities previously done by human personnel, many of these examples additionally are a function of somewhat immature technology design aspects. For example, data sharing across applications is limited, resulting in gaps in information, interface usability lags other industries in sophistication, and 'one size fits all' workflow approaches result in inefficiencies for many. Potential negative impacts to patient safety included an increase in unnecessary care, missed care, delays in diagnoses and treatment, redundant care, inaccurate diagnoses, medication errors, and adverse events.

With this loss of system resilience, it is highly possible that there is no visible increase in erroneous actions. Rather, 'standard' cognitive work (technically five macrocognition) functions have become more challenging to conduct. This increased complexity may be hard to observe in standard usability testing and performance metrics commonly used in healthcare settings. A particularly troubling consequence is a reduction of opportunistic detection of events that occur in the world due to poor information displays which hide changes and trends in data values and a failure to support the detection of others' erroneous actions or intended actions through shared displays which enable cross-checking.

The phenomenon identified in this paper does appear to generalize across multiple care settings and healthcare practitioners. Nevertheless, it is unlikely that losses in system resilience remain unaddressed for long periods of time. Compensatory strategies are likely to evolve both relatively quickly and over time. It is likely that compensatory strategies are initially conducted by individuals with a 'workaround' approach or by sacrificing quality of work-life in ways which are not sustainable over the long-term. When 'workarounds' are generated at local levels with little coordination, then unnecessary variability is introduced, which can then create the need for standardization and relatively minor system improvements such as changes to defaults, threshold settings, template options, and items in drop-down menus. Over longer time periods, new roles might emerge. For example, documentation and 'foraging' tasks could potentially be done by non-clinical supporting staff such as medical scribes or 'documenter' positions.

We believe that traditional patient safety measures, such as adverse events, are insufficient to guide designers in changing existing systems to increase system resilience. When measures are unable to directly detect the phenomenon, a predictable outcome is that the loss in resilience goes undetected. Although we did not explicitly investigate how 'sharp end' practitioners perceive losses in system resilience, it is quite possible that they are

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

incentivized not to bring them to the attention of organizational leaders. For example, implementation of HIT could enable 'sharp end' practitioners to shed resilience-augmenting activities in order to reduce their workload burden, particularly when workload increases with the introduction of new technology. As Health Information Technology (HIT) in particular is being implemented at a rapid pace in hospitals and outpatient settings, there is typically an increase in standardization, automation, and 'decision support systems' (DSS). With this automation, HIT tends to perform some, but not all, of the work previously done by people might result in tasks 'falling through the cracks' more often that are not directly assigned to particular personnel. Put another way, implementation of HIT facilitates 'sharp end' practitioners to shed resilience-augmenting activities in order to reduce workload burdens, even when these dropped activities are not conducted by the HIT or other personnel.

The description of the phenomenon is purposely characterized in domain-independent language to encourage a search for confirmation or modification based on conceptually-driven research in other complex, sociotechnical settings with high consequences for failure. Although we focused exclusively on the loss of resilience in order to increase the likelihood of describing similar patterns, most HIT implementations likely experience gains as well as losses. For example, patients who schedule their own appointments through an automated scheduling system may be able to move other activities to accommodate optimal scheduling of clinical care, thus improving patient outcomes. Nevertheless, our concern is that undetected losses of system resilience is much more problematic than undetected gains. Without making progress on understanding this phenomenon, there is a risk is that HIT interventions will induce unnecessary undesirable patient outcomes. We recommended future conceptually-driven research in other complex, sociotechnical settings order to develop useful metrics and reduce the risk of incurring undesirable and unnecessary impacts on cognitive work associated with new technology.

Acknowledgments

This project was supported by grant number P30HS023558 from the Agency for Healthcare Research and Quality. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality. We thank Emilie Roth, Ph.D., for recognizing how 'work to rule' strikes relate to the phenomenon identified in this article and Sharon Schweikhart, Ph.D., for shaping the discussion of implications of the phenomenon with relation to available patient safety measures and usability testing methodologies.

References

Carrington JM, Effken JA. Strengths and limitations of the electronic health record for documenting clinical events. Comput Inform Nurs. 2011; 29(6):360–367. [PubMed: 21107239]

Collins SA, Fred M, Wilcox L, Vawdrey DK. Workarounds used by nurses to overcome design constraints of electronic health records. Nurs In-form. 2012; 2012:93.

Gephart S, Carrington JM, Finley B. A Systematic Review of Nurses' Experiences With Unintended Consequences When Using the Electronic Health Record. Nursing administration quarterly. 2015; 39(4):345–356. [PubMed: 26340247]

Goldzweig CL, Orshansky G, Paige NM, Towfigh AA, Haggstrom DA, Miake-Lye I, Shekelle PG. Electronic patient portals: evidence on health outcomes, satisfaction, efficiency, and attitudes: a systematic review. Annals of internal medicine. 2013; 159(10):677–687. [PubMed: 24247673]

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

Hirschtick, RE. [Accessed January 4, 2016] Sloppy-and-paste. http://www.webmm.ahrq.gov/case.aspx?caseID=274

Hirschtick RE. John Lennon's Elbow. JAMA. 2012; 308(5):463–464. [PubMed: 22851112]

Hoffman RR, Yates JF. Decision(?)-Making(?). IEEE Int Syst. Jul-Aug;2005 :22–29.

Hogan TP, Wakefield B, Nazi KM, Houston TK, Weaver FM. Promoting access through complementary eHealth technologies: recommendations for VA's Home Telehealth and personal health record programs. Journal of general internal medicine. 2011; 26(2):628–635. [PubMed: 21989614]

Hollnagel, E., Woods, DD., Leveson, N. Resilience engineering: Concepts and precepts. Ashgate Publishing, Ltd; 2007.

Hunter K. Implementation of an electronic medication administration record and bedside verification system. Online J Nurs Inform. 2011:15.

Klein G. Naturalistic decision making. Human Factors: The Journal of the Human Factors and Ergonomics Society. 2008; 50(3):456–460.

Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, Strom BL. Role of computerized physician order entry systems in facilitating medication errors. Jama. 2005; 293(10):1197–1203. [PubMed: 15755942]

Lowry, SZ., Ramaiah, M., Patterson, ES., Brick, D., Gurses, AP., Ozok, A., … Gibbons, MC. Proceedings of the International Symposium of Human Factors and Ergonomics in Healthcare. Vol. 3. SAGE Publications; 2014 Jun. Integrating Electronic Health Records into Clinical Workflow An Application of Human Factors Modeling Methods to Ambulatory Care; p. 170-177.

Lowry, SZ., Ramaiah, M., Taylor, S., Patterson, ES., Prettyman, SS., Simmons, D., … Gibbons, MC. Technical report from National Institute of Standards and Technology. Sep. 2015 Technical Evaluation, Testing, and Validation of the Usability of Electronic Health Records: Empirically Based Use Cases for Validating Safety-Enhanced Usability and Guidelines for Standardization. NISTIR 7804–1.

Nemeth, C., Wears, R., Woods, D., et al. Minding the Gaps: Creating Resilience in Health Care. In: Henriksen, K.Battles, JB.Keyes, MA., et al., editors. Advances in Patient Safety: New Directions and Alternative Approaches (Vol. 3: Performance and Tools). Rockville (MD): Agency for Healthcare Research and Quality (US); 2008 Aug.

Patterson ES, Hoffman RR. Visualization framework of macrocognition functions. Cognition, Technology & Work. 2012; 14(3):221–227.

Patterson ES, Cook RI, Render ML. Improving patient safety by identifying side effects from introducing bar coding in medication administration. Journal of the American Medical Informatics Association. 2002; 9(5):540–553. [PubMed: 12223506]

Patterson ES, Doebbeling BN, Fung CH, Militello L, Anders S, Asch SM. Identifying barriers to the effective use of clinical reminders: bootstrapping multiple methods. Journal of biomedical informatics. 2005; 38(3):189–199. [PubMed: 15896692]

Patterson, ES., Latkany, P., Brick, D., Gibbons, MC., Ramaiah, M., Lowry, SZ. Integrating Electronic Health Records Into Clinical Workflow An Application of Human Factors Modeling Methods to Two Specialty Care Areas. Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care; June 2015; p. 42-49.

Patterson ES, Rogers ML, Render ML. Fifteen best practice recommendations for bar-code medication administration in the Veterans Health Administration. Joint Commission Journal on Quality and Patient Safety. 2004; 30(7):355–365.

Patterson ES, Rogers ML, Tomolo AM, Wears RL, Tsevat J. Comparison of extent of use, information accuracy, and functions for manual and electronic patient status boards. International journal of medical informatics. 2010; 79(12):817–823. [PubMed: 20863752]

Pennathur PR, Thompson D, Abernathy JH III, Martinez EA, Pronovost PJ, Kim GR, … Gurses AP. Technologies in the wild (TiW): human factors implications for patient safety in the cardiovascular operating room. Ergonomics. 2013; 56(2):205–219. [PubMed: 23384283]

Horwitz LI, Parwani V, Shah NR, Schuur JD, Meredith T, Jenq GY, Kulkarni RG. Evaluation of an asynchronous physician voicemail sign-out for emergency department admissions. Annals of emergency medicine. 2009; 54(3):368–378. [PubMed: 19282064]

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

Simpson KR. Electronic health records. MCN: The American Journal of Maternal/Child Nursing. 2015; 40(1):68.

Singh H, Thomas EJ, Mani S, Sittig D, Arora H, Espadas D, Petersen LA. Timely follow-up of abnormal diagnostic imaging test results in an outpatient setting: are electronic medical records achieving their potential? Archives of internal medicine. 2009; 169(17):1578–1586. [PubMed: 19786677]

Sockolow PS, Rogers M, Bowles KH, Hand KE, George J. Challenges and facilitators to nurse use of a guideline-based nursing information system: Recommendations for nurse executives. Applied Nursing Research. 2014; 27(1):25–32. [PubMed: 24360777]

The Joint Commission. [Accessed January 4, 2016] Preventing errors relating to commonly used anticoagulants. Sentinel event alert from The Joint Commission. Sep 24. 2008 http://www.jointcommission.org/assets/1/18/SEA_41.PDF

Vicente, KJ. Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work. Mahwah, NJ: Erlbaum and Associates; 1999.

Woods DD, Wreathall J. Stress-strain plots as a basis for assessing system resilience. Resilience engineering: Remaining sensitive to the possibility of failure. 2008; 1:145–161.

Biographies

Emily Patterson, PhD, is an associate professor in the Health Information Management and Systems Division in the School of Health and Rehabilitation Sciences, College of Medicine at The Ohio State University. She is a member of the Human Factors and Ergonomics Society.

Laura Militello, MS, is the Senior Principal Scientist at Applied Decision Science. She helped organize the second, fourth, and twelfth NDM conferences and serves on the editorial board for JCEDM. She is a member of the Human Factors and Ergonomics Society.

George Su, MD, is an Associate Professor of Medicine at the Division of Pulmonary and Critical Care, San Francisco General Hospital, and the University of California, San Francisco.

Urmimala Sarkar MD, MPH is an Assistant Professor of Medicine in Residence at UCSF in the Division of General Internal Medicine and a primary care physician at San Francisco General Hospital's General Medicine Clinic. Dr. Sarkar's research focuses on (1) patient safety in outpatient settings, including adverse drug events, missed and delayed diagnosis, and failures of treatment monitoring, (2) health information technology and social media to improve the safety and quality of outpatient care, and (3) implementation of evidence-based innovations in real-world, safety-net care settings.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 1

Characteristics of changes associated with implementation of HIT in ambulatory care

Stakeholder groups	HIT	Pre-HIT Workflow	Post-HIT Workflow	Negative Impact on Macrocognition	Negative Impact on Patients
Physician, physician assistant, nurse practitioner	EHR, template, electronic checklist	Review most/all historical documentation one day to a week before a scheduled visit with a patient, the majority of which is noteworthy	Review most/all historical documentation, but only for high-priority or specialty care patients, one day to a week before scheduled visit with a patient. Review one or two progress notes five minutes before or during a scheduled visit with a patient. Typically progress notes have comprehensive documentation of many things, only some elements of which are abnormal or noteworthy. Increased potential for outdated information “cut and pasted” from prior visits, ‘wrong patient,’ data from “cut and pasted” data placed in the wrong chart or entered in the wrong chart, or misleading descriptions from automatically generated text from clinical reminders, smart text, or templates when restricted options result in missing documentation, selecting ‘the closest’ item, or workarounds to increase efficiency include selecting any item quickly. With some systems, extensive interface navigation is required due to information format, such as horizontal scrolling, unnecessary additional blank lines, or lack of word wrap features.	Detecting events: less timely and accurate detection of abnormal lab values or potential anomalies on images when descriptions are unreliable or conflicting Sensemaking: less effective cognitive warm-up	Inaccurate diagnosis, delay in diagnosis, delay in treatment
Physician, physician assistant, nurse practitioner	EHR, inbox, patient portal, e-mail, lab results, consult communications, digital imaging	Receive reminders, highlights, and summaries as annotations or post-it notes on an organized binder outside a patient’s door immediately prior to a scheduled visit with a patient. Receive verbal communications from radiologist or specialist physician	Review some e-mail communications in ‘inbox’ on a periodic basis between scheduled visits, primarily on desktop computer in an office and without easy access to patient or family members. Data are often fragmented and in multiple places.	Detecting events: less timely and accurate detection of events accessed through multiple systems that require ‘foraging’ across multiple displays/areas Sensemaking: less effective framing immediately prior to deciding	Missed care, delay in treatment, adverse events
Physician, physician assistant, nurse practitioner, medical assistant	EHR, progress note, template, electronic checklist, drop-down menus	Conducting and documenting an initial interview led by the patient in his/her own words of the historical and recent narratives	No patient-led interviews conducted. Reliance upon the prior progress note and patients and family members’ responses to queries by the provider to verify information and/or select from available items.	Sensemaking: less effective collaborative framing across stakeholders (physician and patient)	Inaccurate diagnosis, delay in diagnosis, delay in treatment
Physician, physician assistant, nurse practitioner, medical assistant, scribe	EHR, problem list, chief complaint, computer-assisted coding	Reviewing, modifying, and updating a list of problems and/or chief complaint during or immediately prior to or following a visit	Less time spent diagnosing the patient and reviewing problems due to reduced time during visit from additional effort updating problem lists, interacting with the HIT interface, performing additional tasks such as “locking/unlocking” notes, accepting revised text for billing purposes, checking patients in and out, confirming the use or acceptable deviation from best practice recommendations via ‘pop-up dialogs’, or selecting or searching for detailed billing-related data (e.g., ICD-9/10 codes, CPT codes) or entering data required for accreditation, licensing, or regulatory purposes.	Sensemaking: less effective updates to an initial (diagnostic) frame Sensemaking: less effective collaborative framing across stakeholders (multiple physicians, physician assistants, nurse practitioners)	Inaccurate diagnosis, delay in diagnosis, delay in treatment

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

EHR = Electronic Health Record, ICD 9/10 = revision of the International Classification of Diseases Ninth/Tenth Revision, CPT = Current Procedural Terminology

Author Manuscript

Table 2

Characteristics of changes associated with implementation of HIT in inpatient care

Stakeholder groups	HIT	Pre-HIT Workflow	Post-HIT Workflow	Negative Impact on Macrocognition	Negative Impact on Patients
Registered nurse	EHR flowsheet, progress note	Frame an initial assessment of a patient based on a short set of handwritten notes by the clinicians and previous nurses on a paper form with high significance	Occasionally review some of the available comprehensive, systematic, standardized displays of information that include potentially outdated “copy forward” flowsheet documentation from prior time periods for the same patient, hidden text in comments fields, or “copy paste” documentation from the wrong patient in the progress note	Detecting events: harder to recognize trends in data	Missed events, delay in diagnosis, delay in treatment
Registered nurse	e-MAR	Remind physicians to renew automatic stop orders based upon noticing that discontinued medications which are crossed out on a paper medication administration record should be renewed	Automatically stopped orders are not detected by nursing personnel because discontinued medications are not electronically displayed, except on demand.	Detecting events: harder to recognize changes to orders	Medication error
Registered nurse, physician	e-MAR, EHR	Review medication names, dosages, routes, and times on medication administration records	Confirm that a scanner gives a green light after scanning a medication barcode. Confirm that a medication order has the intended time window rather than review actual administration times due to lower accuracy from automated documentation.	Coordinating: less effective cross-checks	Medication error
Registered nurse	e-MAR	New medication orders displayed on ‘color wheels’ on the outside of paper-based chart binders or orders automatically printed to printers on the unit when pharmacists verify them	Nurses login to e-MAR and view new medication orders. Manually refresh the screen to ensure all new orders are displayed.	Detecting events: harder to recognize new orders	Medication error
Registered nurse	EHR, handover display	Review paper chart in order to generate personal crib notes (‘brains’) starting 30 minutes before the shift, add information during the verbal handover, and use throughout the shift to plan activities and jot information down	Arrive at the beginning of the shift and generate personal crib notes (‘brains’) based on the verbal handover, update notes by logging-in and reviewing EHR information as needed, and use throughout the shift to plan activities and jot information down	Sensemaking: less robust basis for initial (assessment) framing	Missed care, redundant care
Physician, registered nurse	EHR, handover display	Verbally provide a report face-to-face or over the phone about a patient or set of patients and answering questions prior to providing care	As needed, review some patients’ written or audio-taped information captured on forms, faxes, and voicemail during the early portion of a shift period.	Coordinating: less effective cross-checks	Inaccurate diagnosis, delay in diagnosis, delay in treatment, missed care, redundant care

EHR = Electronic Health Record, e-MAR = electronic medication administration record

Author Manuscript
Author Manuscript
Author Manuscript
Author Manuscript

Table 3

Characteristics of changes associated with implementation of HIT in transitions from inpatient to outpatient care

Stakeholder groups	HIT	Pre-HIT Workflow	Post-HIT Workflow	Negative Impact on Macrocognition	Negative Impact on Patients
Physician, physician assistant, nurse practitioner, registered nurse	EHR, inbox, e-communications, vital signs, lab results, alerts	Receive recent results from tests and consults in an organized format, such as highlighted in yellow on a printout by a nurse or medical assistant immediately prior to talking with a patient	Rely upon EHR displays, multiple ‘inbox’ communications, faxes, mail, voicemail, or computerized alert messages that are not organized, highlighted, or easily viewed right before a patient visit without first opening a chart and often cannot be simultaneously sent to multiple clinicians or interdisciplinary team members. View some alerts that appear upon login or prior to doing actions. When alerts send to more than one provider, less frequently viewed.	Coordinating: less effective cross-checks	Inaccurate diagnosis, delay in diagnosis, delay in treatment, missed patient events
Case manager, care coordinator, transplant coordinator, discharge planner, physician	EHR patient scheduling, registries, patient portal	Dedicated personnel actively coordinate scheduled inpatient and outpatient care activities and their care providers	Patients schedule their visits directly through HIT.	Coordinating: less effective cross-checks by stakeholders with specialist knowledge	Delay in care, adverse events, unnecessary appointment

EHR = Electronic Health Record

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 4

Characteristics of changes associated with implementation of HIT in emergency care

Stakeholder groups	HIT	Pre-HIT Workflow	Post-HIT Workflow	Negative Impact on Macrocognition	Negative Impact on Patients
Physician, nurse, clerk	e-whiteboard	All clinical personnel anonymously update and view whiteboard information about working diagnoses and assigned providers	Clerks and assigned clinical personnel with logins non-anonymously view and occasionally update some information about working diagnoses and assigned providers after higher-priority tasks like patient registration in EHRs.	Coordinating: less timely and accurate updating of information on shared displays	Inaccurate diagnosis, delay in diagnosis, delay in treatment, missed care, redundant care

EHR = Electronic Health Record, e-MAR = electronic medication administration record