MEDINFO 2019: Health and Wellbeing e-Networks for All
L. Ohno-Machado and B. Séroussi (Eds.)

doi:10.3233/SHTI190303

Usability Across Health Information Technology Systems: Searching for Commonalities and Consistency

Ross Koppel[a,b] and Craig Kuziemsky[c]

[a]University of Pennsylvania, Philadelphia, PA, USA
[b]University at Buffalo (SUNY), Buffalo, NY, USA
[c]Telfer School of Management, University of Ottawa, Ottawa, ON, Canada

Abstract

Usability of health information technology (HIT) remains a predominant concern — one often exacerbated by clinicians' need to access information created by many different professionals in different settings, often using very dissimilar EHRs or even different configurations of the same EHR. Because of these variations, we argue that we must no longer think of usability as anchored in one setting, one EHR, one data standard, or one type of clinician. Rather, usability must be understood as a collective and constantly evolving process. This paper seeks to address that reality by 1) substantially expanding our previously-developed conceptual matrix of the wide range of settings and interfaces comprising modern HIT and 2) presenting actual examples of EHR usability issues with similar data but very different displays or processes.

Keywords:

Ergonomics, patient safety, evaluation studies

Introduction

Healthcare information technology (HIT) usability issues remain a predominant source of medical errors and other undesirable outcomes [1; 2]. While research has identified usability issues in a single system or setting, the challenge of usability across a range of systems remains problematic and far less rigorously examined. Patient care increasingly occurs across multiple providers, settings, and HIT systems. Thus, usability must be considered not just for one system, but across several systems and users. Functions or features in HIT (e.g. data retrieval or display) are seldom consistent across systems, which often leads to errors [3]. Clinicians may have to use several different systems, meaning they will encounter variability in how one logs in and out or enters and searches for data. They will also have to reconcile a wide assortment of fonts and displays. Ash, Berg and Coiera describe how unintended consequences from HIT usage – especially entering and retrieving information – can lead to 'silent errors' that remain prominent today [4; 5].

We cannot uncouple HIT usability considerations in one system from the broader context of how healthcare delivery occurs. The reality of modern healthcare delivery is that providers may have to use multiple systems and will encounter numerous ways of displaying data and of searching for and retreving information [6; 7]. While it may be infeasible to implement a standardized HIT across the many different settings where healthcare delivery occurs, there is a need to understand usability variations to proactively manage unintended consequences. While there is a wide body of research that has looked at ways to improve the usability of individual HIT systems (e.g. [8]), there is a paucity of studies that have looked at cross-system usability to better understand the issues clinicians encounter when they have to use multiple systems.

In previous work, we developed a matrix of eleven usability dimensions and contextual differences to stimulate discussion about usability issues across providers and settings [9]. This paper extends that work by expanding the usability dimensions to fifteen and also by identifying specific usability issues for each dimension. We assembled these examples from our decades of observations, from the human-computer interaction literature, and from lists of problems reported to the IT departments at several hospital systems (e.g. [3; 10-12]). We then provide a set of case examples to illustrate how our matrix helps to better contextualize multi-system usability issues.

Results

Expanded Matrix of Usability Dimensions and Contextual Differences

Table 1 shows our expanded matrix of usability dimensions and contextual differences. The matrix identifies three usability categories or dimensions: 1) Displays, Navigation, and Screen Rules; 2) Implementation, Staffing, and Cost; and 3) Authentication, Staff Access Rules, and Logins/Logouts. We believe these three overarching groups to be significant for cross-system usage. Each group encompasses a set of usability challenges within the dimension and specific factors that account for these challenges. For example, for the first usability dimension (Displays, Navigation, Screen Rules), the first usability issue is differences across electronic health record (EHR) systems and versions. Usability testing needs to account for contextual differences that will exist due to different EHR vendors and versions.

Following the expanded matrix we provide a set of case examples that help to visualize and understand how the specific usability issues described in the matrix vary across different clinical systems. We then illustrate our expanded matrix's utility with examples of multi-system usability issues. Each example refers to specific usability dimensions and issues from Table 1.

Table 1 – Expanded Matrix of Usability Dimensions and Contextual Differences

Usability Category	Usability Challenge	Specific Usability Factors
Displays, Navigation, Screen Rules	**1.** Different EHR systems & versions present data in very different ways. (Often, it is the cost or fear of chaos that inhibits shifting and upgrading.)	EHR vendor & version
	2. Inconsistent and confusing data displays. Fonts, colors, metrics, interfaces and more vary dramatically across systems. Providers become comfortable viewing data in a specific context and may be confused when the display changes. (Figure 1)	Usability displays (font, size, metrics, color schemes, color intensity)
	3. Finding patients and data – there is a high degree of inconsistency in navigation and search functions for patient location data and clinical data (e.g. lab or medication data). Problems locating patients or medical data cause inefficiency and, at worst, can be lethal. **a.** Patient-finding method: by last name, first name, MRN, MDs, unit, room #, team name, etc. **b.** Finding labs, meds, problem lists, etc. (Many different lab and test names for same item; listings can be sorted chronologically, in reverse chronological order, by requester name, by lab facility or lab tech name, alphabetically, by organ system, etc. [Figure 2])	
	4. Rules on the number of screens and patient charts that can be open at one time vary. Each new chart or screen increases the probability of entering an order into the wrong patient chart or reading data from the wrong patient chart. (Figure 3) **a.** ID safety, patient name and photo on each screen: name on every screen, photo on page, photo size, display clarity, position on screen **b.** Number of screens and patient charts open at one time	
Implementation, Staffing, Cost	**5.** The literature reflects myriad conflicts between medical staff and corporate leadership or consultants selected by management. **a.** EHR implementation authority: in-house, system-wide (enterprise) **b.** Role of implementation consultant(s): consultants largely determine configuration, consultants mostly advisory, consultants absent or not in authority	
	6. There may be a false belief that implementation of new EHRs will reduce the need for, size of, and proximity of IT teams.	IT team location (on site, not on site) & size (expanded, stay same size)
	7. Practice size, type and combinations thereof are major factors determining EHR cost, design and configuration.	Clinician type (e.g. MD, RN, NP), practice size (if outpatient), practice type (inpatient vs. outpatient)
Authentication, Staff Access Rules, Logins/Logouts	**8.** Need for repeated logins and complex authentication requirements cause frustration and errors via workarounds and interruptions. Circumvention of access rules creates opportunities for wrong patient errors and unauthorized access. **a.** Authentication (login rules): username, password, card, biometric, two-factor authentication, combination of multiple methods **b.** Number of logins: by type (e.g. for each patient, to give drugs, to order tests), total number per day or hour	
	9. Automatic logout times cause interruptions and prompt workarounds, such as the use of Styrofoam cups to defeat proximity sensors	Automatic logout times (too quick leads to thought & work interruptions, too long leads to security risks)
	10. Access rules that are inconsistent with clinical need and workflow are a major frustration and lead clinicians to share passwords and ID cards. More directly, they may create wrong patient errors by causing confusion about patients and associated data.	Access rules (by role [e.g. MD, RN], status [e.g. admin, clinical], patient, unit)
	11. Often governments or agencies (the FDA, for example) set rules for data formats and drug use. There are also often data formatting requirements from participating labs, drug naming or drug categorizing companies, and other linked facilities. (Figure 4)	Data interoperability requirements (formats can be set by health information exchange policies, cooperating labs or suppliers, governments or other agencies)

Displays, Navigation and Screen Rules

Example of Issue 2 – Inconsistent Displays and Confusing Screens

Figure 1 shows an EHR screen for ordering vitamin K to counteract excess anticoagulation medications causing unwanted bleeding in a patient. The interface presents several problems that make the simple task of selecting a delivery method for vitamin K difficult. The clinician is presented with a screen that offers little guidance or organization, yet offers many choices and options for this critical substance. An alternative presentation of the options, perhaps with decision trees and visually comprehensible categories of conditions, would make the process safer and more efficient.

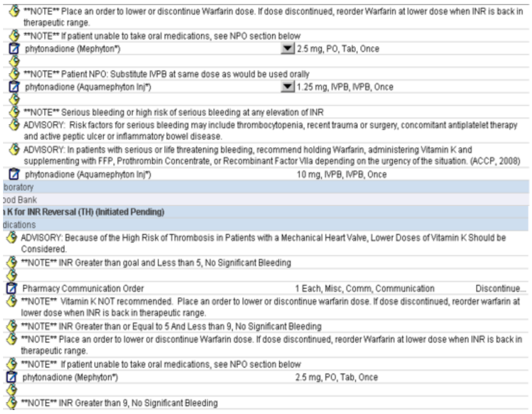

Figure 1 – This EHR screen is for selecting vitamin K to stop bleeding. Chaotic and confusing, it hinders a critical decision.

Example of Issue 3b – Finding Medication Data

Medication ordering errors are the most common form of medical error. There are roughly 4,500 medications in the average hospital formulary, with many more available through pharmacies. Variations in presentation of brand name vs. generic name, doses, routes, schedules, and the like add complexity and danger. Figure 2 provides examples of two different systems. The system in Figure 2A lists the drug name, dose and route in a single field, while the system in Figure 2B shows the generic name, drug name, route and dose in four separate fields. The different displays also have different methods by which drugs can be searched. In the system in Figure 2A, drugs can only be searched and selected alphabetically because there is only one field with all the details. The system in Figure 2B allows drugs to be searched or ordered by any of the fields (e.g. by drug or generic name).

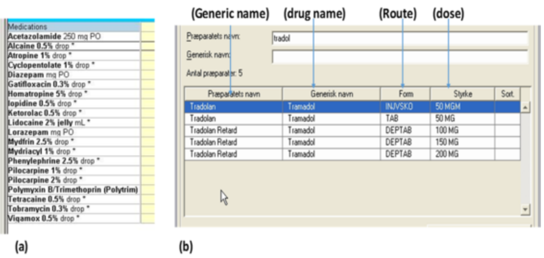

Figure 2 – Medication listings from two different systems

Other EHR systems have yet different configurations of the fields, and some have additional fields such as manufacturer or Anatomical Therapeutic Chemical (ATC) codes [13]. The different order, number of fields, and ordering and display capabilities puts the burden on individual providers to develop heuristics or other strategies to retrieve and interpret necessary information. This can present usability challenges that lead to medical errors and other unintended consequences.

Example of Issue 4b – Number of Screens Open at One Time

Figure 3 highlights the difference between viewing data on a single screen or via multiple screens. By separating the combined chart (Figure 3A) into two screens (Figures 3B and 3C) on the EHR, the pediatrician may be prevented from observing the relationship between the two variables. In this case, the dip ("dent") in weight that is not present in height may indicate gastrointestinal problems, abuse, malnutrition, or other maladies that would be missed due to the isolated charts. (The "dent" in the weight graph is exaggerated to illustrate the data in the small-format illustration; in actual practice, the chart takes up the full screen or page.)

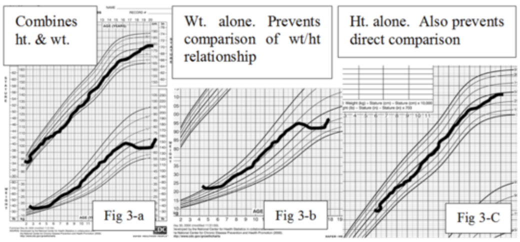

Figure 3 – Standard weight/height chart used by pediatricians for over 100 years (A); display of separate weight chart (B) and height chart (C) in some EHRs

Implementation, Staffing, Cost

Example of Issue 7 – Practice Size, Type and Combinations

Practice configurations can vary significantly depending on context. Usability challenges may be less pronounced in an independent primary care clinic where providers use a single system. Hospitals, however, can present specific usability challenges, as providers often have to access different systems depending on the context of care delivery. Specialty areas such as the operating room often have their own HIT systems.

A recent study of an implementation of a perioperative system provides an example of this issue [14]. Because the system in the study was a real-time system for perioperative data only, other data, such as lab or historical patient data, were not part of the perioperative system; therefore, clinicians needed to access this data in other systems. For example, a patient's pre-op data (e.g. diagnosis, surgical and anesthesia history) and their lab and radiology data were only viewable in the hospital EHR system. This led to two issues. First of all, the EHR system was not routinely used by surgical staff prior to implementing the perioperative system, meaning users had to learn how to use a whole new system. Secondly, and more significantly, the dual systems created a chasm between data from the EHR and data from the perioperative system. Users often needed information from both systems simultaneously. For example, on the day of surgery, a patient's historical data is in the EHR, while the active charting on the patient's case is occuring in the perioperative system. As a result, clinicians have to look at records in two different systems, which creates visualization problems as they need to toggle between two different interfaces. Clinicians commented that they preferred to view the data side by side; thus, they were required to devise innovative ways to acess data across the two systems, such as using an iPad to access the perioperative system and the hospital terminal to access the EHR system.

Authentication, Staff Access Rules, Logins/Logouts

Issue 8a – Authentication and Login Rules

A common challenge to providers moving across settings is the need to log in and out of multiple HIT systems. This issue highights common authentication problems; namely, that many types can be used, including passwords, fingerprints, ID cards, or retinal scans. If providers must use multiple systems with different login systems, usability issues emerge.

Fingerpint readers, for instance, may become bacterial reservoirs, and they cannot be used by clinicians wearing gloves. Many clinicians are reluctant to place their eyes on iris readers, or their eyes may appear to change in response to diabetic retinopathy or cataracts. Clinicians who forget ID cards can be prohibited from accessing their EHR for an entire day.

Issue 9 – Automatic Logout Times Cause Interruptions

Automatic logout is designed as a security feature, but it can also lead to usability problems. In the aforementioned perioperative case study, the system had an automatic logout as a security feature. However, the usability impact of the logout feature was dependant on which perioperative area the clinician worked in. In high-traffic areas, such as surgical day care centers, nurses quickly moved from patient to patient, with only a few fields of data entry for each patient. In this case, the automatic logout was not a problem. However, in the operating room, the anesthesiologist would have the perioperative system open for the duration of the patient's surgery. Some anesthesiologists commented that there would be blocks of time during the surgery when they would not be entering data for a long enough period that the system would log them out. They would then have to log back in and find the patient record yet again. Worse, sometimes an anesthesiologist would pre-configure some of the upcoming data entry and would then lose that configuration when the automatic logout occurred.

Issue 10 – Access Rules

Patients with contagious infections are placed in isolation rooms. To enter those rooms, clinicians wear special gowns and gloves. Those clinicians also cannot roll the mobile computer workstations into those rooms with them. Therefore, they often rely on a colleague in another room or the hallway to access that patient's chart for them. However, the only way they can enter orders and data is by giving their password to the non-isolated clinician colleague or by leaving their computer ID card with the cooperating colleague before entering the room. This violates computer access rules and makes tracking the authors of orders impossible.

Example of Issue 11 – Governments or Other Agencies Often Set Rules for Data Formats and Drug Use

Figure 4 describes an issue at a major hospital with a home-built EHR system. There was insufficient funding to update the vaccine list for pediatricians, so vaccines that were no longer approved and no longer available remained on the EHR menus. If a pediatrician were aware of the change, they could simply prescribe a different vaccine. If the pediatrician were not aware of the change, however, they would prescribe it but the pharmacy would be unable to administer it. Worse, the pediatrician would assume the child was protected when they were not.

Vaccine	Vaccine Schedule and Status
~~ABCD~~	Found ineffective. Use XYZ drug instead
EFGH	Administer at 6 mos. and at 18 mos.
~~IJKL~~	Don't administer. Replaced by UVWX.
MNOP	Administer at 3 mos.
~~QRST~~	Prohibited. Do not use

Figure 4 – Discontinued vaccines remain on drug menus

Discussion

It has been said that consistency is one of the most important design principles for achieving usability [15]. However, the range of existing settings, care delivery models and HIT systems renders it improbable that we will have consistent HIT design guidelines any time soon. Rather, we must develop approaches to best manage the diversity of HIT systems that exist. This paper expands our previous multi-setting, multi-system, and multi-user matrix of usability dimensions [9]. In our ongoing work, we seek to encourage a more panoptic design of HIT software by incorporating the need to focus on usability across several facilities and many software vendors' products, addressing many clinicians' multifaceted needs when they confront substantial interface and functional differences. Frameworks for multi-dimensional usability are needed in settings where there are multiple systems for the same task, such as e-prescribing [16]. An expansion of usability considerations is also needed as we move toward greater collaborative care delivery and must train users in the use of HIT features across multiple settings and systems.

In this paper, we used examples to illuminate how this new and expanded matrix may be operationalized, illustrating how information retrieval methods for clinical data in one system may be inefficient or even impossible in another, and different usability issues users will encounter across different systems. We also highlight usability differences that can occur in the same settings because of different system uses and users across units or departments. Our work seeks to demonstrate how information retrieval differences can lead to serious usability and medical errors. It also emphasizes the need for ongoing user training and education in HIT, as expertise on one HIT system does not assure competence on other systems. Further, the factors differentiating how HIT systems are actually used will encompass not only the vendor's designs, but also the work of local IT teams, local implementation teams, implementation consultants, local regulations, corporate rules, and more. In addition, more modifications will be required due to changing patient and clinician populations, new medications, new mobile applications, patient-provided data, and new procedures.

The usability dimensions and issues we identified focus on our prior studies, which is a limitation of this paper. Other usability dimensions and issues will no doubt exist in other contexts and settings. Our next steps will be to conduct field studies to test our usability matrix across different providers, settings, HIT systems, and care delivery models.

Conclusions

The distributed nature of HIT systems and functions ensure they will always be emergent, interactive and multifaceted. Our approaches to studying usability and HIT must be equally emergent and multifaceted. The old model of a clinician learning and using one system is already superannuated by modern medical practice. As systems struggle to achieve interoperability and effective sharing of data, the need for cross-system commonalities across HIT systems will only increase. When one gets into a car, one assumes the gas pedal is on the right and the brake is on the left; such basic assumptions do not apply to EHRs. In some EHR systems, information access may require a patient's hospital room number; in another system the clinician may need to know the patient's medical record number. In some EHR systems, lab reports are found via the name of the test; in others, via the name of the laboratory or the requesting physician.

Given these variations, we assert that usability must encompass analyses and evaluations of many EHR interfaces as used by many different clincians in a range of settings with diverse implementations. Usability must be conceptualized on both an individual system level and as a collective reality.

References

[1] A. Kushniruk, C. Nohr, S. Jensen, and E.M. Borycki, From Usability Testing to Clinical Simulations: Bringing Context into the Design and Evaluation of Usable and Safe Health Information Technologies. Contribution of the IMIA Human Factors Engineering for Healthcare Informatics Working Group, *Yearb Med Inform* **8** (2013), 78-85.
[2] R. Marcilly, L.W. Peute, M.C. Beuscart-Zephir, and M.W. Jaspers, Towards Evidence Based Usability in Health Informatics?, *Stud Health Technol Inform* **218** (2015), 55-60.
[3] S.W. Smith and R. Koppel, Healthcare information technology's relativity problems: a typology of how patients' physical reality, clinicians' mental models, and healthcare information technology differ, *J Am Med Inform Assoc* **21** (2014), 117-131.
[4] J.S. Ash, M. Berg, and E. Coiera, Some unintended consequences of information technology in health care: the nature of patient care information system-related errors, *J Am Med Inform Assoc* **11** (2004), 104-112.
[5] P.L. Elkin, M.C. Beuscart-Zephir, S. Pelayo, V. Patel, and C. Nohr, The usability-error ontology, *Stud Health Technol Inform* **194** (2013), 91-96.
[6] T. Payne, J. Fellner, C. Dugowson, D. Liebovitz, and G. Fletcher, Use of more than one electronic medical record system within a single health care organization, *Appl Clin Inform* **3** (2012), 462-474.
[7] J.R. Vest and K. Simon, Hospitals' adoption of intra-system information exchange is negatively associated with inter-system information exchange, *J Am Med Inform Assoc* **25** (2018), 1189-1196.
[8] P.Y. Yen and S. Bakken, Review of health information technology usability study methodologies, *J Am Med Inform Assoc* **19** (2012), 413-422.
[9] R. Koppel and C. Kuziemsky, Interface Usability Across and Within EHR Vendors and Medical Settings: The Often Unexamined Need for Interface Similarities, *Stud Health Technol Inform* **234** (2017), 183-187.
[10] K. Stowers and M. Mouloua, *Human Computer Interaction Trends in Healthcare: An Update*, 2018.
[11] P. Carayon and K.E. Wood, Patient safety - the role of human factors and systems engineering, *Stud Health Technol Inform* **153** (2010), 23-46.
[12] C.E. Kuziemsky and A. Kushniruk, Context mediated usability testing, *Stud Health Technol Inform* **205** (2014), 905-909.
[13] A. Kushniruk, J. Kaipio, M. Nieminen, H. Hypponen, T. Laaveri, C. Nohr, A.M. Kanstrup, M. Berg Christiansen, M.H. Kuo, and E. Borycki, Human Factors in the Large: Experiences from Denmark, Finland and Canada in Moving Towards Regional and National Evaluations of Health Information System Usability. Contribution of the IMIA Human Factors Working Group, *Yearb Med Inform* **9** (2014), 67-81.
[14] C.E. Kuziemsky, A Model of Tradeoffs for Understanding Health Information Technology Implementation, *Stud Health Technol Inform* **215** (2015), 116-128.
[15] J. Nielsen, Enhancing the explanatory power of usability heuristics, in: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, Boston, Massachusetts, USA, 1994, pp. 152-158.
[16] Z. Ahmed, Y. Jani, and B.D. Franklin, Qualitative study exploring the phenomenon of multiple electronic prescribing systems within single hospital organisations, *BMC Health Serv Res* **18** (2018), 969.

Address for correspondence

Ross Koppel, Ph.D.
Email: rkoppel@sas.upenn.edu
Phone: 215 898 7679