AHRQ National Web Conference on Reducing Provider Burden Through Better Health IT Design

Presented by:
Pascale Carayon, PhD
Zia Agha, MD
Lukasz Mazur, PhD

Moderated by:
Bryan Kim, PhD
Agency for Healthcare Research and Quality

January 25, 2018
Agenda

• Welcome and Introductions
• Presentations
• Q&A Session With Presenters
• Instructions for Obtaining CME Credits

Note: After today’s Webinar, a copy of the slides will be emailed to all participants.
The following presenters and moderator have no financial interests to disclose:

Pascale Carayon, PhD
Presenter

Zia Agha, MD
Presenter

Lukasz Mazur, PhD
Presenter

Bryan Kim, PhD
Moderator

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PESG, AHRQ, TISTA, and RTI staff have no financial interests to disclose.

Commercial support was not received for this activity.
How to Submit a Question

- At any time during the presentation, type your question into the “Q&A” section of your WebEx Q&A panel.
- Please address your questions to “All Panelists” in the drop-down menu.
- Select “Send” to submit your question to the moderator.
- Questions will be read aloud by the moderator.
Learning Objectives

At the conclusion of this activity, participants should be able to:

1. Identify the cognitive and team work involved in venous thromboembolism (VTE) prophylaxis and the sociotechnical system design requirements that support collaborative VTE prophylaxis teamwork.

2. Describe methods for capturing and analyzing EHR use for providing a comprehensive assessment of usability, clinical workflow, physician-patient communication, cognitive load, and user satisfaction in two distinct outpatient settings.

3. Explain an evaluation to assess provider mental workload and performance on abnormal test result follow-up in both a standard and an enhanced EHR environment that includes results tracking functionality.
Sociotechnical Design of Health IT for Teams Application to VTE Prophylaxis

Pascale Carayon, PhD
Wisconsin Institute for Healthcare Systems Engineering
University of Wisconsin-Madison
Acknowledgments

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- Peter Hoonakker
- Megan Salwei
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- Brian Patterson
- Shashank Ravi [Yale]

Geisinger

- Vaibhav Agrawal
- Jason Stamm
- Ken Wood [University of Maryland]

- Yushi Yang [Drexel]
- Yudi Wang
- Doug Wiegmann
- Emily Wirkus
- Becky Price

https://cqpi.wisc.edu/vte-and-health-it/
Venous Thromboembolism (VTE)

• VTE:
  – Patient safety problem (Goldhaber & Bounaumeaux, 2012; Maynard et al., 2013, 2014)

• Solutions for preventing VTE:
  – Guidelines for VTE prophylaxis
  – Risk assessment algorithms
  – EHR (CDS) to support VTE prophylaxis

• But...
  • Usability, usefulness and workflow integration of health IT
  • Not just admission:
    • Missed doses of enoxaparin → DVT formation [Louis et al., 2014]
  • Collaborative work of physician, pharmacist, nurse, etc...
VTE Prophylaxis in the Hospital
SEIPS Model of Work System and Patient Safety
[SEIPS = Systems Engineering Initiative for Patient Safety]

(Carayon et al., 2006, 2014)
Study Design

• Multiple case study design (Eisenhardt, 1989)

11 cases

4 hospitals

- GMC
  - CCM
  - Cardiology
  - Hospitalist

- GWV
  - CCM
  - CCS
  - Hospitalist

- GSACH
  - CCS
  - IM
  - Hospitalist

- UWHC
  - CCM
  - CCS
  - Hospitalist

CCM=Critical Care Medicine
CCS=Critical Care Surgery
IM=Internal Medicine
Data Collection Methods

- **Survey:**
  - To assess clinician attitudes toward and perceptions of VTE prophylaxis and potential solutions
  - $N=1,009$ (attendings, residents, PA/NP, pharmacists, nurses); 85% response rate

- **Observation:**
  - Focused on morning rounds: VTE-related activities
  - $N=40$; 69 hours

- **Interviews and focus groups:**
  - Based on SEIPS model: What is the work system? System barriers and facilitators?
  - $N=40$; 61 hours

Multiple feedback loops
Results ➔ Sociotechnical Design Considerations

1. Survey
2. Role network analysis
3. Cross-case analysis

Participatory Human-Centered Design
Participatory Human-Centered Design

• Objective:
  – To define design considerations for health IT that supports cognitive and team work in VTE prophylaxis [interruption/re-initiation]

• Divergence/convergence (Brown, 2009-Design Thinking)

• Local and national experts

• Participation of clinical team members

➢ Sociotechnical system
Sociotechnical Design Considerations for VTE Prophylaxis

**focus on interruption & re-initiation**

- 13 categories with 22 specific design considerations:
  1. Patient journey
  2. Clinical appropriateness
  3. Physician teamwork
  4. Role clarity
  5. Built-in redundancy/error recovery
  6. Structure-rounds-shift change
  7. Organizational culture
  8. Workload
  9. Technology access
  10. Environment
  11. Education of nurses and physicians
  12. Education of patients
  13. Unit-level monitoring
Results → Sociotechnical Design Considerations

1. Survey
2. Role network analysis
3. Cross-case analysis
Who is best able to provide *daily assessment* of patient need for VTE prophylaxis?
Sociotechnical Design Considerations

• Need to reduce role ambiguity
  ... but also need for a “second pair of eyes”

• Team configurations and responsibilities

• Automation to monitor and/or suggest interruption or re-initiation

Role clarity

Error recovery (resilience)
Results → Sociotechnical Design Considerations

1. Survey

2. Role network analysis (Hundt et al., 2017)

3. Cross-case analysis
GWV-CCM

Activities in blue = performed during multidisciplinary bedside rounds

GWV-Hospitalist

(Hundt et al., 2017)
Sociotechnical Design Considerations

• Need to support teamwork
  ... in particular communication between attending physician and proceduralists [technology for team communication]

• Transparent, open organizational culture
  ... anyone can suggest interrupting or re-initiating VTE prophylaxis

• Structure for team discussion and team awareness
  ... checklists and reminders in EHR
Results ➔ Sociotechnical Design Considerations

1. Survey
2. Role network analysis
3. Cross-case analysis
Cross-Case Analysis

11 case reports: 11-25 pages each
1. Contextual information
2. Data on VTE process and outcomes [survey, observation]
3. Perceptions of and attitudes toward VTE prophylaxis [survey]
4. VTE prophylaxis across the hospital journey [role network analysis]
5. Roles in VTE prophylaxis [survey]
6. VTE-related team interaction during morning rounds [observation]
7. Perceived barriers to VTE prophylaxis [survey]
8. Possible solutions for VTE prophylaxis [survey]

Cross-case analysis table
[focus on interruption & re-initiation]
Sociotechnical Design
Considerations for VTE Prophylaxis

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Context matters!
Sociotechnical Design Considerations for Care Process

- 13 categories with 22 specific design considerations:
  1. Patient journey
  2. Clinical appropriateness
  3. Physician teamwork
  4. Role clarity
  5. Built-in redundancy/error recovery
  6. Structure-rounds-shift change
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  11. Education of nurses and physicians
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  13. Unit-level monitoring

- Sociotechnical system (SEIPS model)
- Participatory human-centered design
- Multidisciplinary
- Multiple contexts
Contact Information

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Quantifying EHR Usability To Improve Clinical Workflow - QUICK

Funding support AHRQ R01 2012-2016

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Aim 1: Measure and compare EMR use patterns.

• EMR usability must be expressed in operational terms to guide objective comparisons.

• We propose to measure and compare clinicians’ use of EMRs during outpatient visits, based on video recordings, EMR screen capture, and EMR mouse-click and key-click data.
Aim 2: Measure and compare clinical workflow and clinician-patient communication.

• During the limited timeframe of an outpatient visit, clinicians multitask between EMR work and interaction with patients.

• The complexity of the clinical workflow is not directly observable from EMR alone, yet must be taken into account to make meaningful comparisons across visits.

• We propose to measure clinician workflow and clinician-patient verbal communication, based on video recording of visits and coded to a discrete set of behaviors.
Aim 3: Measure satisfaction and cognitive load.

During clinical encounters, clinicians manage multiple needs that impose an administrative and cognitive burden. Therefore, we will measure cognitive burden via the NASA Task Load Index (NASA-TLX), a validated and widely used tool that enables subjective assessments of the workloads associated with those interacting with human-machine systems.
Aim 4: Explore associations between aims 1, 2, and 3.

• To understand real-world EMR usability, we will explore associations between EMR usage, workflow, communication, user satisfaction, and cognitive load.

• Additionally, separate analyses will also be conducted to study the effect of sites (UCSD and VA), clinician types (Primary and Specialty), and EHRs (CPRS and EPIC) on usability and workflow.
Site comparison in terms of care delivery model, staff support, and EHR features.

<table>
<thead>
<tr>
<th>Factor</th>
<th>UCSD</th>
<th>VASD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient study population</td>
<td>Balanced male/female patient demographics</td>
<td>Predominantly male patients</td>
</tr>
<tr>
<td>Scheduled visit lengths</td>
<td>20/40 min visits (Follow up/New patient visit)</td>
<td>30/60 min visits (Follow up/New patient visit)</td>
</tr>
<tr>
<td>EHR</td>
<td>EpicCare Ambulatory</td>
<td>CPRS (Computerized Patient Record System using VistA back-end)</td>
</tr>
<tr>
<td>EHR features, and configuration</td>
<td>• Typically single monitor, but 9 doctors use the dual window</td>
<td>• Dual monitor present in ~35% of visits</td>
</tr>
<tr>
<td></td>
<td>• More levels of menus, objects and paths</td>
<td>• CPRS functions (Notes, Orders etc.) takes up full screen, blocking other functions (even on dual monitor PCs)</td>
</tr>
<tr>
<td></td>
<td>• Associations (Dx to Rx) (no CPRS counterpart)</td>
<td>• Associations for Consults and Imaging but not Dx</td>
</tr>
<tr>
<td></td>
<td>• Non-blocking split screen (used by ~1/2 physicians)</td>
<td>• Real time Care coordination (patient status) not in CPRS but available elsewhere</td>
</tr>
<tr>
<td></td>
<td>• Real time Care coordination - Patient instructions filled in → printed out (often Nurse out of room sees change in real-time visit status “scheduling”)</td>
<td>• Computerized clinical reminder work</td>
</tr>
<tr>
<td></td>
<td>• Epic access logs to profile pre/post work</td>
<td>• Order imaging has more mouse clicks</td>
</tr>
<tr>
<td></td>
<td>• Epic logs to profile patient complexity</td>
<td>• No separate history documentation UI – only notes</td>
</tr>
<tr>
<td></td>
<td>• Voice recognition used only 2 visits</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dual windows allows e.g., working in Notes without blocking other functions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Scheduling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Web links available in Haiku and Canto apps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• History documentation interface is structured</td>
<td></td>
</tr>
</tbody>
</table>
Recruitment by site and specialty groupings

<table>
<thead>
<tr>
<th></th>
<th>UCSD</th>
<th>VASD</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>8/63 (physicians/patients)</td>
<td>9/64</td>
<td>17/127</td>
</tr>
<tr>
<td>Specialty*</td>
<td>7/53</td>
<td>8/43</td>
<td>16/96</td>
</tr>
<tr>
<td>Total</td>
<td>15/116</td>
<td>17/107</td>
<td>32/223</td>
</tr>
</tbody>
</table>

- Specialties included gastroenterology, pulmonology, cardiology, rheumatology, nephrology.
Visit process data

Primary Instruments
- Room Video
  - Nonverbal + clinical workflow
- Usability Software
  - Mouse + keyboard activity
  - Vocalization + verbal activity
  - EHR screen recording

Secondary Instruments
- Body tracking
- Eye tracking

Sensor data restricted to window of the visit
Figure 1: Visit activity

- **Instrument**
  - Post-visit surveys
    - TLX
    - Pre/post workflow
  - Webcam
  - UI capture software
  - Eyetracker
  - EHR logs (UCSD)

- **Activity Signals**
  - Room audio/video
    - Non Verbal**
    - Vocalization**
    - Discourse*
  - EHR display video
    - Mouse clickstream*
    - Keyboard clickstream*
    - Mouse path*
  - Eye gaze path*
  - Mouse activity*

- **Human Coding**
  - Subjective work and cognitive load
  - Clinical work and patient-provider communication

- **Analysis**
  - EHR workflow

Pre, Visit timeline, Post, Longitudinal patient profiling (1 year pre visit)
Summary of data coding quality in terms of intercoder agreement across dual-coded visits.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sample size (visits)</th>
<th>Intercoder agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Method</td>
</tr>
<tr>
<td>EHR CPRS (Aim 1)</td>
<td>n = 15 (15 VASD)</td>
<td>Sequential Tab-level comparison</td>
</tr>
<tr>
<td>EHR Epic (Aim 1)</td>
<td>n = 11 (11 UCSD)</td>
<td>Sequential CPRS-equivalent Tab-level comparison</td>
</tr>
<tr>
<td>NonVerbal (Aim 2)</td>
<td>n = 21</td>
<td>Time-resolved comparison</td>
</tr>
<tr>
<td>Vocalization (Aim 2)</td>
<td>n = 7</td>
<td>Time-resolved comparison</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Averaged sum of speaker time comparison</td>
</tr>
</tbody>
</table>
Comparison of EHR function activity between the two sites based on mouse clicks and timing based on physicians’ gaze-to-EHR.

<table>
<thead>
<tr>
<th>CPRS (VASD) n = 89 (16668 mouse clicks)</th>
<th>Common and frequent tabs in CPRS and epic</th>
<th>Epic (UCSD) n = 106 (8280 mouse clicks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(¹) CPRS “Other” Tabs:</td>
<td></td>
<td>(¹) Epic “Other” Tabs:</td>
</tr>
<tr>
<td></td>
<td>Timing (min)</td>
<td>Count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(¹) CPRS “Other” Tabs:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consults, Cover, Discharge, Patient Selection, Problems, Review/Sign, Surgery, Unidentified</td>
<td>578 (58%)</td>
<td>8300 (50%)</td>
</tr>
<tr>
<td></td>
<td>198 (20%)</td>
<td>4547 (27%)</td>
</tr>
<tr>
<td></td>
<td>55 (5%)</td>
<td>1084 (7%)</td>
</tr>
<tr>
<td></td>
<td>43 (4%)</td>
<td>666 (4%)</td>
</tr>
<tr>
<td></td>
<td>24 (2%)</td>
<td>403 (2%)</td>
</tr>
<tr>
<td></td>
<td>107 (1%)</td>
<td>1668 (10%)</td>
</tr>
</tbody>
</table>
EHR Activity + NonVerbal Gaze / Visit

not all behaviors are considered here, will add up to less than 100% of visit duration
Comparison of CPOE frequency, time-at-task per order and EHR UI burden as measured by numbers of clicks/order

<table>
<thead>
<tr>
<th>Order type</th>
<th>UCSD Orders (n = 106 visits)</th>
<th>Timing median (IQR) seconds</th>
<th>Mouse clicks median (IQR)</th>
<th>VASD Orders (n = 89 visits)</th>
<th>Timing median (IQR) seconds</th>
<th>Mouse clicks median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consult</td>
<td>27 (25%)</td>
<td>49 (29, 75)</td>
<td>11 (8, 15)</td>
<td>44 (49%)</td>
<td>52 (36, 82)</td>
<td>16 (11, 24)</td>
</tr>
<tr>
<td>Imaging</td>
<td>22 (21%)</td>
<td>47 (28, 85)</td>
<td>8 (6, 11)</td>
<td>20 (22%)</td>
<td>43 (28, 70)</td>
<td>12 (6, 17)</td>
</tr>
<tr>
<td>Lab</td>
<td>32 (30%)</td>
<td>12 (6, 28)</td>
<td>4 (3, 6)</td>
<td>44 (49%)</td>
<td>12 (7, 19)</td>
<td>5 (3, 7)</td>
</tr>
<tr>
<td>Med</td>
<td>54 (51%)</td>
<td>38 (24, 78)</td>
<td>10 (6, 13)</td>
<td>54 (61%)</td>
<td>26 (18, 47)</td>
<td>9 (7, 12)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (5%)</td>
<td>3 (25, 93)</td>
<td>6 (5, 8)</td>
<td>6 (7%)</td>
<td>6 (8, 32)</td>
<td>4 (4, 14)</td>
</tr>
<tr>
<td>Reminder</td>
<td>5 (5%)</td>
<td>9 (6, 11)</td>
<td>5 (4, 6)</td>
<td>33 (37%)</td>
<td>19 (14, 32)</td>
<td>5 (4, 7)</td>
</tr>
<tr>
<td>Return to Clinic</td>
<td>58 (55%)</td>
<td>12 (7, 30)</td>
<td>3 (2, 4)</td>
<td>37 (42%)</td>
<td>25 (16, 47)</td>
<td>9 (8, 14)</td>
</tr>
</tbody>
</table>
Figure 4
Distribution of navigation across EHR functions. Tab-level transitions based on mouse clicks tagged to the top-level screen or “Tab” coding.

<table>
<thead>
<tr>
<th>Tab-level transitions (count)</th>
<th>Study pop. n = 195 (100%)</th>
<th>By site UCSD 106 (54%)</th>
<th>By specialty VASD 89 (46%)</th>
<th>By specialty Primary 113 (58%)</th>
<th>By specialty Specialist 82 (42%)</th>
<th>By status New 41 (21%)</th>
<th>Established 154 (79%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 (9,27) (median, IQR)</td>
<td>22 (13,34)</td>
<td>12 (8,22)</td>
<td>21 (11,32)</td>
<td>14 (8,22)</td>
<td>15 (10,26)</td>
<td>17 (9,29)</td>
<td>48</td>
</tr>
</tbody>
</table>
EHR Navigation patterns for one randomly selected visit for each study physician, based on mouse click activity human-coded to top-level Tab or EHR screen.

Each colored square represents a transition between major EHR functions or “Tabs” (e.g., Notes?Orders).

The number of Tab transitions is shown to the right of each navigation sequence.
## Cognitive load ratings and rank orders - NASA TLX

<table>
<thead>
<tr>
<th>Activity measure</th>
<th>Subjective workload (TLX subscale)</th>
<th>Sample size (physicians)</th>
<th>Physician-aggregated correlation</th>
<th>Rank (based on median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visit Length (minutes)</td>
<td>Effort (5-item)</td>
<td>n = 32 (100%)</td>
<td>0.49 (0.12, 0.67)</td>
<td>1</td>
</tr>
<tr>
<td>EHR Tab (screen) transitions (count)</td>
<td>NegPerformance (2-item)</td>
<td>n = 32 (100%)</td>
<td>0.42 (-0.36, 0.63)</td>
<td>2</td>
</tr>
<tr>
<td>EHR Tab (screen) transitions (count)</td>
<td>Effort</td>
<td>n = 32 (91%)</td>
<td>0.38 (0.14, 0.61)</td>
<td>3</td>
</tr>
<tr>
<td>Epic Log Size (count)</td>
<td>Effort</td>
<td>n = 16 (50%) UCSD</td>
<td>0.35 (0.24, 0.52)</td>
<td>4</td>
</tr>
<tr>
<td>EHR Mouse Clicks (count)</td>
<td>Effort</td>
<td>n = 32 (100%)</td>
<td>0.32 (0.03, 0.6)</td>
<td>5</td>
</tr>
<tr>
<td>Gaze Dominance (ratio)</td>
<td>Effort</td>
<td>n = 32 (100%)</td>
<td>0.28 (-0.07, 0.58)</td>
<td>6</td>
</tr>
<tr>
<td>Charlson Comorbidity Index (raw)</td>
<td>Effort</td>
<td>n = 24 (75%)</td>
<td>0.27 (-0.29, 0.54)</td>
<td>7</td>
</tr>
<tr>
<td>Charlson Comorbidity Index (raw)</td>
<td>NegPerformance</td>
<td>n = 24 (75%)</td>
<td>0.26 (-0.23, 0.47)</td>
<td>8</td>
</tr>
<tr>
<td>EHR Mouse Path Length (pixels)</td>
<td>Effort</td>
<td>n = 32 (100%)</td>
<td>0.23 (-0.06, 0.56)</td>
<td>9</td>
</tr>
<tr>
<td>Verbal Patient Concerns (count)</td>
<td>NegPerformance</td>
<td>n = 25 (78%)</td>
<td>0.21 (-0.22, 0.32)</td>
<td>10</td>
</tr>
<tr>
<td>EHR Keystrokes (count)</td>
<td>Effort</td>
<td>n = 31 (97%)</td>
<td>0.20 (-0.07, 0.49)</td>
<td>11</td>
</tr>
</tbody>
</table>
## Gender in NASA TLX

<table>
<thead>
<tr>
<th>Question</th>
<th>Male</th>
<th>Female</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental demand</td>
<td>9.5</td>
<td>4.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Physical demand</td>
<td>10.5</td>
<td>4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time pressure</td>
<td>9</td>
<td>7</td>
<td>0.022</td>
</tr>
<tr>
<td>Successful in EHR</td>
<td>18</td>
<td>15.5</td>
<td>0.045</td>
</tr>
<tr>
<td>Both mental and physical</td>
<td>11</td>
<td>9</td>
<td>0.024</td>
</tr>
<tr>
<td>Stress level</td>
<td>5</td>
<td>5.5</td>
<td>0.78</td>
</tr>
<tr>
<td>Satisfied with interaction</td>
<td>15</td>
<td>15.4</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Bonferroni adjustment $p < 0.007$ indicates statistical significance.
Correlation of CPOE activity and effort rating on TLX
Figure 5
Summary

We demonstrated a novel approach to collecting and analyzing multiple sources of data during clinical activities and integrated these streams into meaningful measures, enabling comparison across two clinical settings with different EHRs and a spectrum of primary and specialty (outpatient) care.

This effort revealed a high degree of variation in observed activity and clinical practice despite accounting for similar types of visits and patient complexity.

We identified similar patterns of EHR use and navigation at the 2 sites despite differences in functions, user interface, and consequent coded representation.

Both sites displayed remarkably high burden (frequency and time at task) to attended to EHRs along with high subjective workload as measured by NASA Task Load survey.
Summary

Commonly noted high-level clinical tasks, such as medication reconciliation or preventive care were highly distributed across the visits and very difficult to measure, suggesting the need for further levels of integration.

Preliminary workload analyses suggested a complex relationship between levels of measurable physicians’ activity during visits and perceptions of effort and task performance.

As no single visit activity factor was highly correlated with subjective task load, a fuller understanding of the workflow and cognitive flow will require integration of qualitative data, e.g., physician interviews.
QUICK Team

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Reducing Provider Burden through Better Health IT Design – Part 3

Providers’ Interaction with EHRs

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Acknowledgment

• **Federal Project Officer:** Steve Bernstein, AHRQ, CEPI, Division of Health IT

• **Grant Number:** R21HS024062

• **Co-PI:** Carlton Moore MD, Lawrence Marks, MD

• **Investigator:** Prithima Mosaly, PhD

• **UNC Epic consultant:** Amy Coghill, MSN, RN, OCN

• This study was supported by the grant 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.

**Acknowledgment:** Dr. Donald Spencer, Professor; Vice President and Chief Medical Informatics Officer, UNC Health Care.
Health IT and Patient Safety
Building Safer Systems for Better Care

• Health IT can improve patient safety and quality of care and should be widely embraced (Bates 2003; Ash 2009).

• For example, Hill (2013) found that providers seeing (on average per hour) 2.4 patients require about 4,000 mouse-clicks in EHRs during a 10-hour shift.

• Reports focused on EHR-related medical malpractice identified over 80% of the reported events involve patient harm (Garber 2015).

However, little published evidence could be found quantifying the magnitude of the risk.
The Joint Commission Report on EHR-related errors (n=120)

- **Usability** 33%
- **Workflow and communications** (high/variable workload) 24%
- **Policies & procedures** 6%
- **Actions** 6%
- **Harm**

A complimentary publication of The Joint Commission
Issue 54, March 31, 2015
Specific Aims

To **quantify** the effect of:

- EMR environment (baseline/enhanced)
- Volume (low/high) of abnormal test results on providers’ experienced **task demands**, **workload**, and **performance**.

Our focus was on follow-up of **abnormal** test results, and the baseline and enhanced EMR environment used for the study was Epic®.
• Clinicians fail to acknowledge over one-third of the EHR alerts for critically abnormal imaging studies (Singh 2007).

• Even when providers acknowledge abnormal results, 7-10% of patients still do not receive timely follow-up (Singh 2009; Hysong 2010, 2011).

• The likelihood for lack of timely follow-up doubles with dual-alert communication in which providers receive abnormal results for other providers’ patients (Zapka 2010).
Human Factors Laboratory

- VisionTrack ISCAN
- Tobii X-60
- SMI glasses
- BrainVision
- ABM EEG
- NeXus
- Epic Playground
- Mosaiq
- PLUNC
- Elekta Emulator
- Computers
- Printers
- Phones
Total of **38 residents** from the school of medicine at one large academic institution participated in this study, all with sufficient experience with EHR (Epic) as related to our simulated scenarios.

<table>
<thead>
<tr>
<th>Specialty</th>
<th># of Participants</th>
<th>Post Graduate Year (PGY)</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PGY: count</td>
<td></td>
</tr>
<tr>
<td>Internal Medicine</td>
<td>14</td>
<td>1:4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:3</td>
<td></td>
</tr>
<tr>
<td>Family Medicine</td>
<td>4</td>
<td>1:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:1</td>
<td></td>
</tr>
<tr>
<td>Pediatrics</td>
<td>9</td>
<td>1:3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:0</td>
<td></td>
</tr>
<tr>
<td>Surgery (general, neuro, ortho, head &amp; neck)</td>
<td>5</td>
<td>1:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5:1</td>
<td></td>
</tr>
<tr>
<td>Other (cardiology, psychiatry, critical care, ob/gyn)</td>
<td>6</td>
<td>1:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5:1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>1:10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2:08</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3:11</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4:06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5:03</td>
<td></td>
</tr>
</tbody>
</table>

**Gender: F: female; M: male**

F: 24, M: 14
Study Design

Session 1: Current Epic Environment
- Recognition of Abnormal Results
- Track & Follow-up on Planned Diagnostic Evaluation

Session 2: Current (n=20) vs. Enhanced (n=18) Epic Environment
- Recognition of Abnormal Results
- Track & Follow-up on Planned Diagnostic Evaluation

Providers (n=38) randomized

Low vs. High volume of abnormal test results
Session 1: Current Epic Environment

'Low' volume

35 Results
- 8 abnormalities
- 27 normals

'High' volume

35 Results
- 16 abnormalities
- 19 normals

familiarize themselves with our experimental conditions and practice the simulated scenarios.
In both sessions participants were asked to recognize and act upon abnormal test results.

**Session 1:**
Current Epic Environment

- 'Low' volume
- 35 Results: 8 abnormals, 27 normals

**Session 2:**
Current vs. Enhanced Epic Environment

- 35 Results: 4 abnormals ('no-show'), + 4 abnormals
- 32 Results: 8 abnormals ('no-show'), + 5 abnormals

familiarize themselves with our experimental conditions; practice.

50-60 per interaction with EHR; with 10-15 abnormal test results
### Planning Sheets

<table>
<thead>
<tr>
<th>Tested</th>
<th>Patient</th>
<th>Scenario</th>
<th>Normal Result</th>
<th>Abnormal Test</th>
<th>Flag?</th>
<th>Abnormal Result</th>
<th>Follow-up Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IreneTRES</td>
<td>62F seen by PCP &amp; scheduled for routine screening mammo.</td>
<td>CBC, TSH, Lipid</td>
<td>Mammo</td>
<td>NO</td>
<td>BI-RADS 4. Suspicious abnormality. Biopsy is recommended.</td>
<td>Refer to Breast clinic</td>
</tr>
</tbody>
</table>

#### Notes
- 75 master patients; 12 reserved provider logins; 175 hours to plan, build, test (about 5 weeks)
Current Epic Design
Experienced task demands:

- navigation clicks (e.g., moving from one window to another window on the screen, etc.),
- decision clicks (e.g., accepting/cancelling a test or medication, etc.),
- search clicks (e.g., initiating the search option for medications/orders/etc.),
- total clicks (sum of navigation, decision, and search clicks).
Quantification of perceived workload

- NASA-Task Load Index (NASA-TLX), a widely applied and valid tool, was used to measure perceived workload.
Data Collection

Quantification of physiological workload

– eye tracking
– electroencephalography [EEG]
Data Collection

Quantification of physiological workload

– eye tracking
  • Tobii X2-60, 60Hz remote eye tracker and Eyeworks data recording software.
  • baseline measures, task-evoked pupillary response (TEPR) and blink rate (Mosaly 2017).

– electroencephalography [EEG]
  • X-10 wireless EEG headset system from Advanced Brain Monitoring (ABM)
  • bi-polar sensor sites: Fz, F3, F4, Cz, C3, C4, POz, P3, P4.
Data Collection

- **Quantification of performance**
  - unacknowledged abnormal test results (identified by failure to order a referral, medication or additional testing)
  - unacknowledged patients with ‘no-show’ status for their scheduled appointments (identified by failure to follow up with ‘no-show’ patients)
  - total amount of time that participants took to complete each session.
Data Analysis

• Multivariable analysis of variance
  – Pooled data (all results combined)
  – Abnormal vs. ‘no-show’

• Participants as a random factor.

• All our data analyses were conducted using JMP 13 software with significance level set at 0.05 (normality: all p>0.05; equal variance: all p>0.05; suitable for parametric analysis).
## Results – Task Demands
- Pooled data

<table>
<thead>
<tr>
<th>Current-EMR (Low-volume)</th>
<th>Current-EMR (High-volume)</th>
<th>Task Demands (average per scenario)</th>
<th>Enhanced -EMR (Low-volume)</th>
<th>Enhanced-EMR (High-volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>390(91)</td>
<td>496(110)</td>
<td>Total Clicks (count) †</td>
<td>396(83)</td>
<td>479(118)</td>
</tr>
<tr>
<td>223(73)</td>
<td>276(76)</td>
<td>Navigation Clicks (count)</td>
<td>239(75)</td>
<td>286(78)</td>
</tr>
<tr>
<td>120(22)</td>
<td>155(29)</td>
<td>Decision Clicks (count)</td>
<td>106(25)</td>
<td>124(47)</td>
</tr>
<tr>
<td>46(17)</td>
<td>63(14)</td>
<td>Search Clicks (count)</td>
<td>51(18)</td>
<td>69(24)</td>
</tr>
</tbody>
</table>

- High-volume of abnormal test results generated significantly more total clicks when compared to the low-volume of abnormal test results condition ($p<.01$).
### Results – Task Demands
- Abnormal vs. No-show

<table>
<thead>
<tr>
<th>Current-EMR (Abnormal)</th>
<th>Current-EMR (No-Show)</th>
<th>Task Demands (average per result)</th>
<th>Enhanced-EMR (Abnormal)</th>
<th>Enhanced-EMR (No-Show)</th>
</tr>
</thead>
<tbody>
<tr>
<td>33(11)</td>
<td>28 (12)</td>
<td>Total Clicks (count) †</td>
<td>31(12)</td>
<td>21(9)</td>
</tr>
<tr>
<td>17(7)</td>
<td>15(7)</td>
<td>Navigation Clicks (count) †</td>
<td>16(6)</td>
<td>11(5)</td>
</tr>
<tr>
<td>5(2)</td>
<td>4(2)</td>
<td>Decision Clicks (count)</td>
<td>5(3)</td>
<td>3(2)</td>
</tr>
<tr>
<td>11(4)</td>
<td>9(5)</td>
<td>Search Clicks (count) †</td>
<td>9(2)</td>
<td>6(4)</td>
</tr>
</tbody>
</table>

- Enhanced-EMR, specifically for patients with ‘no-show’ status, indicated lower task demands as quantified by **total**, **navigation**, and **search** clicks (p<.01).
Results – Subjective Workload
- Pooled data

<table>
<thead>
<tr>
<th>Current-EMR (Low-volume)</th>
<th>Current-EMR (High-volume)</th>
<th>NASA-TLX</th>
<th>Enhanced-EMR (Low-volume)</th>
<th>Enhanced-EMR (High-volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>48(15)</td>
<td>58(13)</td>
<td>NASA-TLX (0=low to 100=high)</td>
<td>49(18)</td>
<td>49(13)</td>
</tr>
</tbody>
</table>

- Analysis of NASA-TLX scores indicated no significant differences (p>.05).
- NASA-TLX > 55 are associated with degradation in performance (Hart, 2006; Mazur, 2013, 2016).
On average, human eye blinks 20-25/minute.

Blink rate was significantly lower in the current-EMR (p=.01), suggesting higher mental workload (Mosaly 2017).

<table>
<thead>
<tr>
<th>Current-EMR (Low-volume)</th>
<th>Current-EMR (High-volume)</th>
<th>Physiological Workload</th>
<th>Enhanced -EMR (Low-volume)</th>
<th>Enhanced-EMR (High-volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15(9)</td>
<td>17(7)</td>
<td>Blink Rate (blinks/minute)</td>
<td>24(10)</td>
<td>22(6)</td>
</tr>
</tbody>
</table>
### Results – Physiological Workload
- Abnormal vs. No-show

**Current-EMR (Abnormal)**  
**Current-EMR (No-show)**  
**Enhanced-EMR (Abnormal)**  
**Enhanced-EMR (No-show)**

<table>
<thead>
<tr>
<th></th>
<th>Blink Rate (blinks/minute) †</th>
<th>Power of Fz (6-7 Hz) - Pz (8-10 Hz) (μV²)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>18(9) 0.8(0.4)</td>
<td>19(9) 0.9(0.6)</td>
<td>24(11) 0.9(0.7)</td>
</tr>
</tbody>
</table>

- Blink rate was significantly lower in the current-EMR, specifically for ‘no-show’ (p<.01) patients, suggesting higher mental workload.
- Power of Fz (6-7Hz) – Pz (8-10 Hz) was significantly less in enhanced-EMR, specifically for ‘no-show’ patients (p=.02), suggesting ‘less optimal’ information processing efficiency (Klimesh, 1999).
## Results – Performance

<table>
<thead>
<tr>
<th>Current-EMR (Low-volume)</th>
<th>Current-EMR (High-volume)</th>
<th>Performance</th>
<th>Enhanced -EMR (Low-volume)</th>
<th>Enhanced-EMR (High-volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>6</td>
<td>Clinical Performance†</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td>-missed abnormal results</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>26:12(7:48)</td>
<td>37:18(10:24)</td>
<td>-missed to follow-up on ‘no-shows’</td>
<td>28:54(6:12)</td>
<td>34:12(12:06)</td>
</tr>
<tr>
<td>2:20(0:58)</td>
<td>2:42(1:00)</td>
<td>Time-to-complete (min) †</td>
<td>2:25(0:49)</td>
<td>2:30(1:12)</td>
</tr>
<tr>
<td>1:48(0:36)</td>
<td>2:06(1:13)</td>
<td>Abnormal results only:</td>
<td>1:36(0:48)</td>
<td>1:25(0:46)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time to Scenario Completion (min:sec) †</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>‘No-show’ results only:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time to Scenario Completion (min:sec) †</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Significant improvement in performance in the enhanced-EMR (p<.01).
- Significant longer time to complete scenarios in the high-volume of abnormal test results condition (p<.01).
- Significant less time to process patients with abnormal test results in the enhanced-EMR (p<.01), specifically with no-show status (p<.01).
Reducing Provider’s Burden
- Abnormal & No-Show

<table>
<thead>
<tr>
<th></th>
<th>Performance (total # of errors)</th>
<th>Task Demand (total clicks)</th>
<th>Average Time to Complete a Result (min:sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced EMR (n=189)</td>
<td>0</td>
<td>23</td>
<td>1:51</td>
</tr>
<tr>
<td>Current EMR (n=210)</td>
<td>0</td>
<td>32</td>
<td>2:27</td>
</tr>
</tbody>
</table>

Given 50 results per interaction: **450 clicks and 30 min**!
Conclusions

• Need to ‘optimally’ design features of the EMR to focus providers attention on:
  – i) abnormal test results
  – ii) patients’ status, both with enough detail to facilitate (or not facilitate) appropriate follow-up communications.
• Develop and publicize policies and guidelines regarding work practices and demands to ensure appropriate levels of workload and performance.
• Innovative education/training requirements (e.g., simulation based training vs. traditional training) and performance feedback systems could be organized and implemented (Mazur 2017).

Limitations

• One experiment with relatively small number of participants from one teaching hospital, performed on set of scenarios.
• Time between simulated sessions varied from 1 to 3 weeks, which could have unexpectedly bias the study due to some carryover effects between sessions.
• Day and time of the day to conduct assessments varied, which could have also affected the results.
• Simulated environment, where the subjects knew that their work was going to be assessed, may have affected participants’ performance.
• Reporting workload via NASA-TLX is subjective and can be challenging for some participants.
• Quantification methods of physiological workload, while validated and broadly used, may not fully considered potential confounding factors streaming from cognitive information processing or general cognitive states.
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Questions
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• Select “Send” to submit your question to the moderator.
• Questions will be read aloud by the moderator.
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