Cognitive Science Approach to Understanding Human-Computer Interaction in Medicine

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Role of Computerized Physician Order Entry (CPOE) Systems in Facilitating Medication Errors

JAMA 2005;293:1197-203.
Another Case

Potassium chloride (KCl) ordered as IV injection and as IV fluid additive using vendor’s CPOE system:

- 85-year-old patient, admitted to the medical ICU with septic shock and respiratory failure
- Patient received 316 mEq KCl over 42 hrs (very large amount!) in setting of acute and chronic kidney failure
- High dose delivered due to errors and misperceptions by several care providers
- Compounded errors propagated through the system over three days


Analysis of Failure

- Poor System feedback
- Lack of alerts (warnings) when potassium value reached a dangerous level
- Misconceptions about the relation between IV volume (humans) and time duration (system)
- Inadequate clinical user training regarding safe and efficient ordering practices
Orders entered using a workstation or a wireless device

Alerts, decision support

Hospital Information System
Patient Medical Records
Knowledge Bases

Designing for Safety

- Health information technology (HIT) has reduced the risk of serious injury for hospitalized patients
- Paradoxically, some systems may give rise to hazards of their own
- Errors are the product of cognitive activity in human adaptation to complex environments
- How well the design of HIT complements its intended setting and purpose is critically important for safe and effective performance

Dimensions of Human Computer Interaction (HCI)

Technological
  – Hardware and Software Advances

Cognitive
  – Representation
  – Knowledge Organization
  – Reasoning and Strategies

What is Cognitive Science?

Multidisciplinary field incorporating theories and methods from psychology, linguistics, philosophy, anthropology, and computer science in the investigation of cognitive processes in humans and machines
Typical Experimental Methods

- Naturalistic field studies: Ethnography
- Participant observation
- Use of think aloud protocols
- Study of naturally occurring discourse: Discourse analyses
- Interviews: semi-structured questionnaires
- Case studies
- Video recordings

Specific Methods

- Shadowing of medical team personnel during ‘Crucial Periods’ pertinent to the individual
- Conducting brief interviews to gain insight on infrastructure, roles, shifts, timings
- Mapping the activities to the ICU/ER layout and time-stamping each interaction or event
- Obtaining log files of the clinical information systems and attempting correlation with observational data
Think-Aloud Protocol Reveals Underlying Thought Process

Methods of Analysis

• Task and activity analysis

• Meaningful relations between ideas and concepts (semantic), higher level understanding (conceptual), and context-sensitive (pragmatic) representations

• Dialogue analysis for team communication

• Protocol analysis

• Usability analyses
From Cognitive Science to Medical Cognition

Cognitive Science Theory
- Memory
- Knowledge Organization
- Problem Solving
- Heuristics/Strategies
- Computational Theory of Mind

Medical Cognition Conceptual Frameworks
- Medical Problem Solving
- Organization of Clinical and Basic-Science Knowledge
- Diagnostic Reasoning Strategies
- Medical Decision Making

From Medical Cognition to Biomedical Informatics

Medical Cognition
- Medical Problem Solving
- Organization of Knowledge
- Diagnostic Reasoning Strategies
- Medical Decision Making
- Text Comprehension and Problem Representation
- Development of Medical Expertise
- Medical Discourse

Biomedical Informatics
- Knowledge and Data Representation
- Management of Medical Information
- Human-Technology Interaction
- Cognitive Models for Enhancing Decision Support
- Cognitive Assessment of Usability and Interfaces
- Targeted Training
Clinical Applications and Cognition

- Effects of technology on human behavior
- Clinical workflow for triage decision making and technological support
- Evaluation of device
  - Infusion pump

Effect of an EMR System on Human Cognition

- Transition from paper records to EMR and back to paper record
- Impact on knowledge organization, reasoning
- Information and other technologies are not merely tools to expedite, facilitate and enable the execution of task

Information in EMR and Hand-Written Records

<table>
<thead>
<tr>
<th>Category of Information</th>
<th>Hand-Written Patient Record</th>
<th>Computer-Based Patient Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chief Complaint</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>2. Past Medical History</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>3. Life Style</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>4. Psychological Profile</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>5. Family History</td>
<td>7</td>
<td>14</td>
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<tr>
<td>6. History of Present Illness</td>
<td>55</td>
<td>27</td>
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<tr>
<td>7. Review of Systems</td>
<td>52</td>
<td>8</td>
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<tr>
<td>8. Physical Examination</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>9. Diagnosis</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>10. Investigation</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>11. Treatment</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>TOTAL ENTRIES</td>
<td>304</td>
<td>225</td>
</tr>
</tbody>
</table>

First section from paper-based record (Pre-EMR)

74 year old woman, whose diagnosis was made in February, as she complained of polyuria/nocturia and fatigue for a few years. She was told her sugar was very high and she was sent to Dr. K., who started her on Diabeta 5 mg/d and sent her to Dr. S. in ophthalmology who reported normal retina. She lost weight, her polyuria improved, her bladder urgency got better, and her glucose values improved dramatically. She does no monitoring at home. She had to be hospitalized for an ankle fracture after falling on ice, for 3 months. At follow-up, Dr. K. seemed pleased with the results.
First Section from Electronic Medical Record (EMR)

CHIEF COMPLAINT: Type II diabetes mellitus

PERSONAL HISTORY
SURGICAL: cholecystectomy: Age 60 years old
MEDICAL: hypothyroidism: asymptomatic since 25 years

LIFE STYLE

MEDICATION
DIABETA (Tab 2.5 MG)
Sig: 1 tab(s) Oral before breakfast
SYNTHROID (Tab 0.125 MG)
Sig: 1 tab(s) Oral before breakfast

HABITS: smoking: 0 alcohol: 0

First Section from Paper-Based Record (Post-EMR)

Diabetes type I X age 4
Currently on N54 - N28
R6 - R2 Measure with OT II
Glucose levels: <130 130-180 >180
AM
Lunch
Supper
Bedtime

Last HbA_1c since April 96: 7.4/7.2/6.7/6.6/8.9 - higher values in log book
Retinopathy: NIL March 97
Nephropathy: NIL Oct. 96
Diagnostic Reasoning

Paper Record

Patient Data

Multiple Hypotheses

Return to Paper Record

Same as EMR!

Structure of Medical Knowledge in Problem Solving

SYSTEMS LEVEL

DIAGNOSTIC LEVEL

INTERMEDIATE CONSTRUCT

FINDING LEVEL

OBSERVATION LEVEL
Influence of Technology on Human Cognition

• Information and other technologies are not merely tools to expedite, facilitate and enable the execution of tasks

• Optimal design requires sensitivity to internal organization of concepts by human beings

Clinical Applications and Cognition

• Effects of technology on human behavior

• Clinical workflow for triage decision making and technological support

• Evaluation of Device
  – Infusion pump
Collaborative Cognition

1. Team members
2. Representation
3. Data sources

Intellectual Partnership

- Distributed cognition
- Human-computer interaction analysis

- Knowledge resides partly in the environment
Coordinating internal (user’s mind) and external (interface, environment) resources

References


Overview of Clinical Workflow in the Emergency Department

Patient walks into ED

- Ambulance Patient
- Patient usually assigned to Routine care
- Triage
- Non-Urgent
- Urgent
- Assigned to Urgent care or Psych ER
- Critical patients are transported to receive immediate attention
- Patient transported to waiting area
- High Priority
- Point of Potential Errors

Workflow (Continued)

- Attending Physician
- ED Resident
- Nurses
- Staff
- Point of Potential errors
- Point of interruptions
- Immediate intervention
- Consultation
- Teaching
- Documentation
- Point of Multitasking
Clinical Workflow in Emergency Room Triage

Proposed Clinical Workflow in Emergency Room Triage
Clinical Applications and Cognition

- Effects of technology on human behavior
- Clinical workflow for triage decision making and technological support

- Evaluation of Device
  - Infusion pump

Example of Product Evaluation

Heuristic Evaluation of Infusion Pump

Heuristic Evaluation to Assess Infusion-Pump Problems

- Make system status visible
  - No indication of mode: testing vs. operating mode

- Provide good error messages
  - Problem: “Check internal battery” refers to a battery on the circuit board, not the main battery

- Provide informative feedback
  - Problem: Same audible alarm for all errors

- Prevent errors
  - Problem: default drug concentration inappropriate for some agents
Minimize Memory Load

• Violation: To delete a session user must remember either the session number or date—neither provide much semantic information about the session topic

Effect of Training on Heuristic Evaluation

• Three groups of evaluators

22%—Novices

41%—Single experts

60%—Double experts

Percent of usability problems found
Some Lessons from Cognitive Studies

• Design suitable for environment (uses)
• Technology offers both advantages and pitfalls
  – Monitor for intended and unintended outcomes
• HIT requires systematic cognitive testing
  – Formative (during design and implementation)
  – Summative (after implementation permits assessment of outcomes)

User-Technology Interaction: Role of Cognition

- High
  Sophistication of Typical User
  Unfilled Technology Need
  Technology Delivers Basic Need
  Technology is "good enough" User Experience Dominates

Low
  Sophistication of Technology
  System Complexity Masked from Lay User
  Current Trend